Vol. 25 October, 1931 No. 2

QUARTERLY

OF THE

National Fire Protection Association

For Members only, Annual Subscription $3.00.

Entered as second-class matter December 15, 1928, at the Post Office at Boston, Mass., under act of March 3, 1879.

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Reports of fires appearing in the Quarterly are copies of or extracts from written reports forwarded to the Association. This Association, as a body, is not responsible for the statements or opinions of any of its members.

Wm. E. Patterson.

Airplane view of burned buildings of Little Sisters of the Poor Home for the Aged at Pittsburgh. Forty-eight lives were needlessly sacrificed in this fire on July 24, 1931. Combustible interior construction, unprotected vertical openings, absence of automatic sprinklers or automatic fire alarm, all contributed to the rapid spread of the fire. With inadequate exit facilities, locked gates and doors to retard rescuers, and no watchman on duty, a large loss of life was inevitable when fire started from spontaneous ignition of oily material in a wooden closet under the stairs. (Report of this fire on page 111.)

The Quarterly

Vol. 25 October, 1931 No. 2

Fire and Water Department Coöperation. Consideration given to fire problems by two important regional meetings of waterworks superintendents last month points clearly to the increasing realization by waterworks authorities of their essential relation to the community fire problem.

At a meeting of the New England Waterworks Association in Boston on September 30, Mr. C. W. Mowry (Member N.F.P.A.) presented a paper showing the amount of water required for the extinguishment of major fires and conflagrations, and pointed out the very large peak loads imposed upon water supply systems. A general discussion followed which showed the keen realization by waterworks authorities of the necessity of adequate provision for fighting such exceptional fires. The discussion showed a practical unanimity of opinion between the waterworks authorities and the fire department and other fire protection men who were invited to participate in the discussion.

At Niagara Falls, N. Y., on September 24, Member Edwin Lee Ballard spoke before the New York section of the American Waterworks Association on the general subject of coöperation between water and fire departments, likewise receiving enthusiastic response from the waterworks authorities. Mr. Ballard pointed out the importance of coöperation between the two departments and suggested that this coöperation be arranged through definitely constituted machinery consisting of a committee made up of representatives of the two departments to meet at regular intervals, agree upon matters of policy and act upon all features where the interests of the fire and water departments are both concerned.

One of the points covered at both the New York and New England meetings was the determination of the capacity of hydrants and suitable marking of hydrants in accordance with their capacity. A plan which has already been put into effect in the State of Maine is the grading of hydrants into three different classes, A, B and C, in accordance with the capacity of the hydrants and the mains to which they are connected. The plan is to indicate the capacity of the hydrants by markings of different colors so that the firemen can tell at a glance upon arriving at a given hydrant whether two pumpers can be connected to that hydrant or whether it may be necessary to move

one of the pumpers to another point in order to secure a proper water supply. Such marking, particularly if made uniform by all cities, should be of very great value in fire fighting, especially in cases of conflagration or other large fires where aid is called from other cities. The marking is likewise of value to the waterworks superintendent, enabling him to tell at a glance the capacity of the hydrant and distribution system in a given area.

Another interesting feature referred to independently at both meetings is the use of fire department pumpers to pump into a small town water system in case of a large fire. Reference was made to the Spencer, Iowa, fire which occurred last June, where fire department pumpers were stationed at a river and, using hose with double female connections, pumped into the system and made it possible to control the fire. Polluted water was thus introduced into the system, but it was possible to warn householders, and no epidemic followed. A somewhat similar case was referred to at the New York meeting, where Mr. Ballard described a similar emergency hose connection between a large city supply and the limited system of an adjoining small community that was threatened with destruction by fire.

Other items discussed at both meetings included the arrangements for increased pumping and higher pressures during fires, types of hydrants and methods of arrangement of valves, general planning for emergencies and other features where the coöperation of fire and water departments seems most essential.

Circumstances may vary in different communities, but in all cases close coöperation between the water and fire departments is of utmost importance. The constructive discussion of these common problems at these recent meetings by representatives of fire and water authorities, who each appreciate the problems of the other and recognize the necessity of coöperation, is a most encouraging sign of progress.

* * * * *

Pier Fire Protection. In the July issue of the QUARTERLY detailed accounts were published on two waterfront conflagrations—those occurring in Norfolk on June 7 and Halifax on June 22. Editorial reference was made to these two fires as illustrative of the serious conflagration hazards presented by combustible piers and wharves and the very serious fire losses experienced by this class of property over a long period of years.

In this QUARTERLY there is a detailed description of how this problem has been solved in one important port, New Orleans, where complete automatic sprinkler installation, subdivision by water curtains and other features of protection reduce the hazard to a minimum. The American Association of Port Authorities has been coöperating closely with the N.F.P.A. in the development of recommendations for fire safe pier and wharf construction.

The Good Practice Recommendations on this subject developed as a result of this coöperation were adopted by the N.F.P.A. at the 1931 annual meeting. This report was officially adopted at a meeting of the port authorities in September, thus officially throwing the influence of the Association of Port Authorities towards fire safe pier and wharf construction. The constructive action at New Orleans may be but a forerunner of general action at other ports in the interest of fire safety.

Over a long period of years the pier and wharf fire loss record has been particularly bad, with average losses per fire many times those in any other occupancy. The present developments point clearly towards progress in the protection of existing structures and proper construction for piers and wharves to be erected in the future.

* * * * *

All in the Life of a Fireman. The life of a fireman, contrary to popular belief, is on the whole a rather unexciting one. Day in and day out he responds to trivial fires in grass, rubbish or dumps, or to an occasional fire in an automobile, and answers many false and needless alarms. Serious fires calling for quick action and hard work are few and far between. Probably few can better testify to this than Chief Will Burnett of the Des Moines Fire Department, who has been fighting fires for over 36 years. Therefore he considers June 27, 1931, on which he was treated to more excitement in one day than in many years of fire fighting, something of a red-letter day in his life. For on that day he fought his first fire in a sky-scraper, saw his first major conflagration, and had his first ride in an airplane.

The 23-story Equitable Life Building dominates the skyline of Des Moines' principal mercantile district. Fire broke out on the 19th floor that Saturday afternoon. This floor was used for storage of office supplies, and was sprinklered. The sprinklers failed, perhaps due to a closed valve, so that the fire department had the whole job of handling the fire, which had pretty well involved the entire floor by the time they arrived.

To complicate the situation further, an inexperienced fireman coupled a line at the street to the wrong pumper connection, so firemen who went up to the floor on fire found no water at the standpipes. Unwilling further to delay the attack on the fire, Chief Burnett ordered a hose line dropped the 19 stories down the side of the building and by direct pumping secured a stream with which the fire was finally controlled.

This stream was hardly in action, however, before he was singled out by an agitated representative of the Des Moines *Register*, who reported that a conflagration was in progress at Spencer, Iowa, a city of about 5,000 population, 150 miles away. The city's water was exhausted, he reported, and said that the *Register* had promised to send Chief Burnett and some dynamite by

airplane to aid the blazing city. Chief Burnett reluctantly agreed to go because he felt that if there was no water there was little he could do. He refused to be a party to the use of dynamite, which he knew had seldom been of any value in a conflagration.

The 150-mile airplane ride was made without mishap. Before the plane landed Chief Burnett ordered the pilot to circle the fire three times, flying as low as possible. This maneuver gave him a chance to size up the fire, to observe its extent and see where each fire company was working. The fire, he could see, had burned about as far as it was likely to, but the plane landed and the Chief was able to assist by stopping several ill-advised attempts to use dynamite, which had already added needlessly to the damage done by the fire without in any way retarding its spread.

* * * * *

Gasoline Shower. An editorial in the July QUARTERLY related the experience of an air pilot who was compelled to make a forced landing due to a fire in the plane caused by a cigarette stub discarded by one of the passengers. Another landing was recently forced in Brooklyn by a circumstance which further illustrates the casual character of some of our air-minded folk. A press dispatch tells the story:

> NEW YORK, July 24 (UP)—The second attempt at a transatlantic flight in a week failed today when Russell Boardman and John Polando, young Massachusetts fliers, dumped their load of gasoline and returned to Floyd Bennett airport a few minutes after taking off for Turkey.
>
> Loaded with 728 gallons of gasoline, their monoplane, *Cape Cod,* sped down the long runway and took to the air over Jamaica bay. The heavy weight of gas, however, held the ship low, and it was barely 20 feet in the air.
>
> When the plane reached Brooklyn on the other side of the bay from the Barren Island field it was barely skimming housetops. Boardman was at the control. He dumped 415 gallons of gasoline and the *Cape Cod* rose higher as he swung it around and brought it back to the field. Gasoline sprayed out behind over the houses.
>
> "We probably spoiled someone's breakfast and I'm sorry about it, but it was a matter of life or death," he said, as he clambered out.

The idea of these gentlemen actually taking off for so remote a destination as Turkey without previously ascertaining the weight their plane would sustain in flight is an arresting one. The gasoline shower they were led to project over Brooklyn roofs might easily have spoiled more breakfasts than one.

Little Sisters of the Poor Home Fire, Pittsburgh.

Report by William E. Patterson, Pittsburgh Fire Department,
and
Board of Fire Underwriters of Allegheny County, Pa. (Member N.F.P.A.).

Forty-eight aged men and women lost their lives as a result of burns or suffocation, or died later in hospitals from shock and after effects, when fire swept through the Little Sisters of the Poor Home for the Aged in Pittsburgh on the night of July 24, 1931. From the standpoint of loss of human life it was the most disastrous fire that has ever visited an institution of this kind in the United States or Canada. (See Frontispiece.)

Building and Occupancy.

The burned structure was located practically in the center of a large plot of ground bounded by Penn Avenue, South Aiken Avenue, Coral Street and South Atlantic Avenue, as shown by the accompanying diagram. It was surrounded by a ten-foot brick wall, having locked iron gates at the several entrances. The building, built approximately fifty-eight years ago, was of brick and wood joist construction, four stories, basement and attic in height, with hipped slate roof on wood sheathing, and covered an area slightly exceeding 19,000 square feet. All floors were of double $\frac{7}{8}$-inch wood, the upper floor being hardwood. An 18-inch concealed space created by a false ceiling existed along the corridors on the first floor. All stairways were open and of wood construction, as were also the dumb-waiter shafts. All doors at entrances to dormitories from corridors were of wood with large plain glass panels.

The first floor of the building was practically a basement, the floor of which was located about four feet below the level of the institution grounds. It was occupied by the kitchen, dining rooms, male inmates' sleeping quarters, laundry, wash-house and various rooms used for storage. The second and third floors were used as dormitories for both male and female inmates, and the fourth floor was occupied as the infirmary. The large loft or attic between the fourth floor and the roof was used for the storage of trunks, beds, bedding, wheel chairs and other material.

Dining halls were located on all four floors, with dumb-waiter shafts connecting same with kitchen on the first floor. A convent, chapel, dormitories and offices for the nuns, as well as a chapel for the inmates, were located in other wings of the building.

Private and Public Fire Protection.

First aid protection consisted of extinguishers of the dry powder tube type, two being located on each floor. There were also two 2-inch standpipes, each having a $1\frac{1}{2}$-inch outlet on each floor to which was attached 25 feet of

1½-inch linen hose and a ½-inch nozzle. These standpipes were connected with the city water mains by a 4-inch service line. There were no pumper connections on the outside of the building. The institution was not provided with an automatic fire alarm system, but a city fire alarm box was located within the building, and another was located at the corner of Penn and South Aiken Avenues across the street from the Home.

The water supply in the vicinity of the institution was adequate, there being 30-, 20- and 6-inch mains surrounding the block. The number of fire hydrants and their location was sufficient for the concentration of an adequate number of hose streams.

The burned building was inspected at regular intervals both by members of the fire fighting force and the inspectors from the Fire Prevention Division of the Fire Department, the last inspection being made on April 28, 1931. At that time everything was found to be in good order, no rubbish, waste paper or other fire hazard conditions being noted, and fire department officials considered the condition of the building satisfactory with due allowance for its age and type of construction.

Exit Facilities.

Seven exits to the street were provided on the first floor of the building. From the upper floors, other than the interior stairways, the only means of exit were by way of two iron fire escapes located at the northwest and southeast ends of the building, extending from the fourth floor to the ground level. These fire escapes were not only steep and narrow, but they passed ordinary plain glass windows in wooden frames.

Access to these escapes was through doors to dormitories and thence to windows which either had to be opened or broken, after which it was necessary to climb over a window sill. In many cases windows were provided with iron grille work, which was locked and had to be broken open. Considering the nature of the inmates housed in this institution the exit facilities could hardly be considered suitable or adequate for emergency purposes.

Cause of the Fire.

On the afternoon of the fire the hardwood floors were oiled and scraped by one of the inmates. The inmate stated that he applied linseed oil to the floors with rags and then proceeded to scrape same with an electrically operated scraper which had a cloth bag or container attached to catch the scrapings.

At 4:45 P.M., approximately five hours before the fire broke out, this inmate deposited the scraping machine in a closet beneath a stairway on the first floor leading from outside (Penn Avenue side) to the second floor, the cotton bag still containing some of the scrapings. The oily rags he used were burned in the smoke house located in a separate part of the institution. From

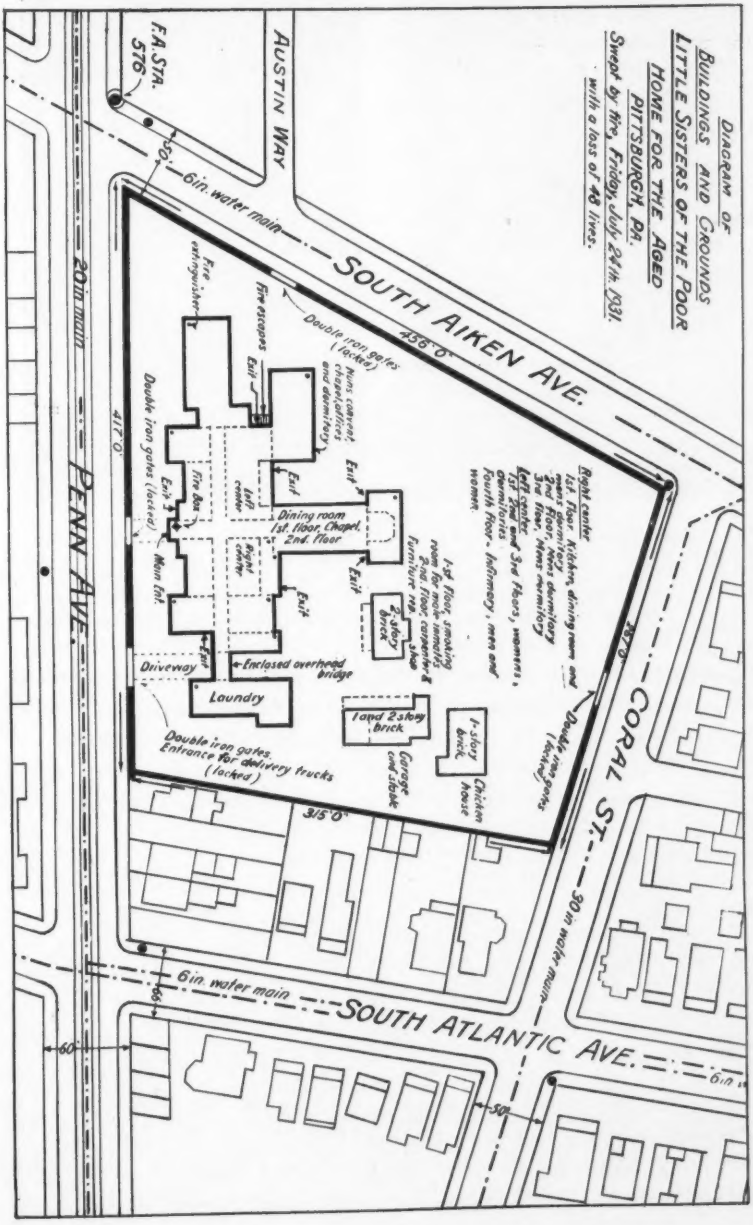


DIAGRAM OF
BUILDINGS AND GROUNDS
LITTLE SISTERS OF THE POOR
HOME FOR THE AGED
PITTSBURGH, PA.
Swept by fire, Friday, July 24th, 1931.
with a loss of 48 lives.
F.A. STA. 576
AUSTIN WAY
SOUTH AIKEN AVE.
6in. water main
436'0"
Double iron gates (locked)
Fire escapes
Fire extinguisher
Exit
Nurses' convent chapel, offices and dormitory
Exit
Exit
Exit
Fire Box
Exit
Double iron gates (locked)
Main Ent.
Dining room 1st. floor, Chapel, 2nd. floor
Right center 1st. floor, Kitchen, dining room and chapel. 2nd floor, Nurses dormitory 3rd floor, Nurses dormitory
Left center 1st. floor and 3rd floors, women's dormitories 2nd floor, Infirmary, men and women
1st floor, sewing room for neck-wears 2nd floor, carpenter & furniture rm.
Exit
Exit
Exit
Fire
Driveway
Enclosed overhead bridge
Laundry
2-story brick
1 and 2 story brick
Garage and stable
1-story brick
Chicken house
Double iron gates (locked)
CORAL ST.
315'0"
Double iron gates. Entrance for delivery trucks (locked)
417'0"
20in. main
PENN AVE.
6in. water main
SOUTH ATLANTIC AVE.
60'
50'
6in. w

Wm. E. Patterson.

The remains of the floor scraping machine and burned out cupboard beneath the main staircase. The battalion chief in the foreground is pointing to the hole burned through the closet floor.

One of the rear stairways in the Little Sisters of the Poor Home for the Aged, Pittsburgh. It was by way of this stairway and other vertical openings that the fire reached the upper floors and attic.

all indications the fire evidently had its origin in the closet beneath the stairway, due no doubt to the spontaneous ignition of the oily scrapings.

Story of the Fire.

The nuns and inmates at the home (all of whom were over 64 years of age) had retired for the night by 9:00 P.M. on the evening of the fire. Previous to that time all doors at the entrances to the building and the iron gates in the brick wall enclosure surrounding the grounds were locked.

From all reports the fire was discovered at approximately the same time by a number of different persons in the immediate neighborhood of the institution. Two young men, seeing the fire raging on the first floor in the rear of the building, rushed to the main entrance on Penn Avenue only to find the gate locked. They rattled the gates and shouted to attract the attention of the inmates and nuns, but there was no response. In a short time others arrived and they proceeded to scale the wall and rushed up the stone steps to the main entrance of the building only to find the doors locked. These men then gained access to the various floors of the building by means of the outside fire escapes and proceeded to arouse and rescue the inmates.

In the meantime a passer-by sounded an alarm from the city fire alarm box 576, located at corner of Penn and South Aiken Avenues. When the first

fire company arrived the large iron gates at the main entrance had been opened by civilians, but the double heavy wooden doors at the main entrance of the building were still locked. Firemen opened these doors with axes.

By this time the fire had gained considerable headway and was spreading rapidly to the attic and upper floors by way of an open stairway located about sixty feet south of the origin of the fire. The fire found its way unnoticed to the open stairway through the false ceiling along the first floor corridors on the upper floors. It spread laterally through the corridors, thus cutting off escape from the dormitories.

While a large proportion of the firemen responding to the alarms were occupied in rescuing the aged and infirm inmates and removing the dead and injured from the building, other firemen were successfully coping with the fire, which, with its headway due to the delay in discovery, threatened to sweep the entire structure. Through the efforts of the fire department the fire was confined to the two top floors and roof of the main building and connecting wings, and badly damaged the second, third and fourth floors of the rear central portion of the main building. The property loss is estimated at about $100,000.

Loss of Life.

At the time of the fire there were 235 inmates housed in the institution; 20 were bed-ridden, eight totally blind, and 190 were active and capable of taking care of themselves (of these, 60 were only able to go about the floor which they occupied). Forty-eight of these aged inmates perished—3 dying from burns, 11 from burns and suffocation, 18 from suffocation, 7 from suffocation and after effects, and 9 from shock and after effects.

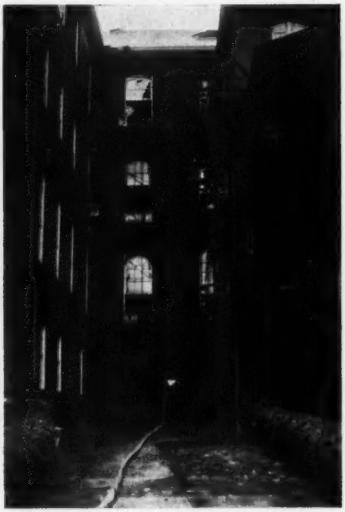
Some of the inmates, most of them women, perished when they rushed back to get their shawls and slippers. They were burned or suffocated before they could be reached and led or carried out of the building by firemen or civilian rescuers. Others were bed-ridden and unable to make their way to safety.

Neighbors helped the firemen and policemen in the rescue work and in caring for the injured. In their attempt to help it is said that many of the citizens who rushed to the scene of the fire crowded the fire escapes and hampered and delayed the firemen in their work of getting the inmates down ladders and fire escapes from the burning building to places of safety. Doctors and nurses, responding to calls for medical assistance, administered first aid to the injured, after which they were sent to the various hospitals as quickly as possible, while the dead were sent to the morgue.

Sister Agatha, the Mother Superior of the burned institution, who occupied an apartment with sleeping quarters on the third floor, stated that upon discovering the building on fire she ran to the rear of the building to open the doors leading to the fire escapes. Following this she tried to extinguish the fire at

Wm. E. Patterson.

Large double doors at main entrance to Little Sisters of the Poor Home for the Aged, Pittsburgh, which were still locked when the fire department arrived.



Fire escape and open porches at South Aiken Avenue end of building. This was one of the two steep and narrow outside means of exit available.

the dumb-waiter shaft, up which flames were rushing, with a hose stream from the standpipe. In the excitement and bewilderment which followed upon being aroused from their sleep by the cry of "Fire," neither the aged Mother Superior, nuns nor inmates thought to sound an alarm from the private city fire alarm box in the building. Instead, one of them rang an old style hand operated alarm bell in the building, used as a signal bell to attract the attention of the inmates. The box in the institution was operated later.

The large loss of life can be clearly attributed to the delay in discovery of the fire, the delayed alarms, the inadequate and improper exit facilities, and lack of organized fire drills.

Delay in Alarm.

The first alarm was sounded over the city fire alarm telegraph system from box No. 576, located at the corner of Penn and South Aiken Avenues at 9:17 P.M. When the captain of Engine Company No. 6 arrived on first alarm the fire had gained considerable headway, and he immediately went to box No. 576 to send in the second alarm. Upon opening the box to send in his signals he heard an alarm operating through this box, thus proving that the box located inside the institution, which is on the same circuit, had just been pulled. The captain sent the five additional alarms to the fire alarm telegraph operator by telephone. It was testified at the coroner's inquest that the smell

Wm. E. Patterson.

One of the dormitories where the helpless old people were suffocated or burned.

of burning wood was very noticeable in the neighborhood for at least thirty minutes before the first alarm was sent in.

Response to Alarms and Fire Fighting.

Eighteen engine companies and four truck companies answered the six alarms of fire. The first alarm at 9:17 P.M. was answered by Engine Companies Nos. 6, 8 and 28, and Truck Company No. 8; second alarm at 9:22 P.M. by Engine Companies Nos. 14, 25 and 26, and Truck Company No. 14; third alarm at 9:25 P.M. by Engine Companies Nos. 7, 16 and 24, and Truck Company No. 25; fourth alarm at 9:29 P.M. by Engine Companies Nos. 2, 38 and 24; fifth alarm at 9:30 P.M. by Engine Companies Nos. 12, 32 and 33; sixth alarm at 9:37 P.M. by Engine Companies Nos. 3, 48 and 58, and Truck Company No. 9.

In extinguishing the fire twenty pumper and five hydrant streams were used through 1,000 feet of 3-inch, 15,460 feet of 2½-inch, and 1,050 feet of 1-inch hose. The ladder companies raised 1,071 feet of ladders. The duration of the fire was ten hours and sixteen minutes.

Findings of the Coroner's Inquest.

An investigation of the fire was made by a coroner's jury. While holding that the deaths were accidental, the jury recommended that immediate steps be taken to ascertain existing measures for the protection of the lives of the inmates of institutions of this sort. They strongly urged, in view of the

responsibility that must be assumed in regard to the young and old harbored in such institutions, that steps be taken to learn of the safety devices which can be recommended for their protection and have such recommendations presented to the governing powers of all municipalities throughout Allegheny County to be passed as ordinances, the same to be retroactive.

This recommendation of the coroner's jury was made not only to those who serve in official capacity as public servants, but also to the administrative bodies of the various institutions.

Lessons of the Fire.

1. The building, owing to its large area and combustible construction, together with the nature of its occupancy, should have been provided with a system of automatic sprinklers, and all floor openings such as stairways and dumb-waiter shafts should have been enclosed and protected in a standard manner.

2. The loss of life would have been considerably less if better exit facilities had been provided. Smoke barriers and draft stops consisting of light partitions and swinging doors should have been provided in the corridors at intervals to retard the spread of smoke and flame for a sufficient period to permit safe egress.

3. Concealed spaces such as false ceilings should be avoided, as they permit flames to spread unnoticed. Unventilated closets are no place for the storage of cotton mops, oily rags, etc. Under no circumstances should storage closets be located underneath stairways.

4. All institutions of this character should be provided with an automatic fire alarm system.

5. Seriously ill, blind and disabled inmates should be on the ground floor, and facilities provided whereby beds may be readily wheeled out without removing patients.

6. Night watchman service should be provided in all institutional buildings.

7. All attendants, employees and capable inmates should be carefully instructed regarding common fire hazards, the use of extinguishing equipment and the method of sending in an alarm. Proper attention should be given to fire drills.

Securing the Co-operation of Employees.

By A. L. Armstrong (Member N.F.P.A),
Eastman Kodak Company, Rochester, N. Y.

We believe that coöperation of employees can be obtained by proper education and a knowledge of our policy in regard to fire prevention. We also believe that this education must start in the employment department. It is a part of the employment manager's duty to impress upon the new employee the fact that we have certain definite rules and standards which everyone in our plants must live up to. We feel that it is also his duty to explain to the employee in a general way the necessity of studying the book of rules which he receives at the time of his employment.

When a new employee goes into a department the foreman explains to him any special hazards with which he may come in contact and tells him what precautions should be taken in order to avoid having a fire.

After the employee has been on the job for two weeks and has had an opportunity to find out something about the way his department is operating, he comes to the safety department, where he is given a quiz to determine just how much he knows in regard to the general rules and to discuss any rule that is not clear. He is given an opportunity at this time to ask any question he may have in regard to safe practices pertaining to his work.

In order to impress on his mind the necessity of handling materials in certain definite ways, we have set up a course of instruction to teach the employee why it is necessary to do things in a certain way, also the reason for different types of safeguards.

Men who work around flammable solvents have an opportunity to see the different types of solvents burn. They also have an opportunity to see different types of extinguishers used for extinguishing solvent fires. We explain to them why one type of extinguisher will work on one type of solvent fire and not on another.

When we run demonstrations we discuss in a general way the flash point, ignition temperature and explosive mixture. One of the examples we use is to point out that the breaking of a gallon bottle of solvent in a room 10x10x10 feet may, under certain conditions, render the air in this room explosive, and if an explosion of maximum intensity occurs it can exert a pressure of 90 pounds per square inch.

We not only discuss proper grounding of tanks and equipment and the handling of solvents, but we actually demonstrate what will happen when static charges are built up and discharged. How the human body, insulated

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Address before National Safety Council, Chicago, October 16, 1931.

by rubbers, will build up static charges which will jump to ground and ignite solvent vapors, and how some solvents, while being poured from a pail by a man with rubbers on (providing the pail is not grounded), may build up a charge sufficiently strong to jump to ground and ignite the vapors. We demonstrate how important it is to prevent damage to ground wires by the following method: we use a static collector, first showing how the charge is carried through the wire to ground, then breaking the wire and building up a sufficient charge to jump the gap.

We also ignite solvent vapors with static sparks, and discuss fires which have been caused by static electricity, not only in our own but in other plants.

Men who work around flammable solids get the same type of education as those working around solvents. We show these men how friction will generate heat and ignite not only flammable but also combustible materials. This is done by the use of a motor with a 4-inch pulley, running about 1000 R.P.M. The material we wish to ignite is placed between a piece of wood and a piece of perforated metal. This is brought up against the pulley to show how quickly sufficient heat is generated to cause ignition.

Another example is the electric light bulb. If a 150- or 200-watt light is used, a cloth can be ignited very quickly, and it is even possible to ignite wood by laying a bulb on it, providing the upper part of the bulb is covered up.

The short-circuiting of electric wires is demonstrated, and we discuss frankly the hazards connected with the use of improper extension cords. We also discuss fires which have been caused by equipment of this kind.

We point out hazards connected with over-fusing of a panel board or the use of hay wire or bolts in place of fuses, and also the fact that electric light lines are put in for a specific number of certain sized lamps, and if larger sized lamps are used overloading of wires and cables will result and may cause a fire.

In regard to hazards of motor installations in industrial plants, we discuss this subject in some detail. Motors which must operate in atmospheres subject to flammable vapors or finely divided dust should be constructed for these conditions and be properly approved for use in hazardous locations. Of greatest importance is frequent and thorough inspection service. We discuss different phases of the problem with the employees for the purpose of preventing them from piling combustible materials on motors, turning a water hose on them, or using conduit boxes as steps. We also point out that it is a part of their job to watch equipment of this kind closely and report immediately any motor that is, in their opinion, overheating or in any way out of order.

To demonstrate how heat from a radiator or steam pipe will ignite flammable material, we use an electrically heated hot plate of about the same temperature.

Employees who handle acids and caustics receive the same type of instruction—by demonstration—and our men who handle cylinders of flammable gases receive definite instructions as to their respective hazards. Whenever it is possible, we have the supervisors of departments handling these materials look over accidents or fires which may have occurred within the city where our plant is located. We have in our organization an expert inspector on acetylene equipment who inspects all of the portable equipment in the plant and has the authority to stop the use of any equipment which, in his judgment, creates a hazard.

We find that improper tools, such as electric drills, extension cords, steel hammers and steel knives, are often the cause of fires where flammable materials are handled. This also includes wrenches which might be used on drums or tanks and on pipe connections.

One of the most difficult facts to get over to the average employee is that a drum or tank car from which flammable solvents have been pumped offers a much greater hazard than a full drum of such liquid. The explosion test, we believe, is the best method of getting this over to the employee. By using a too rich mixture it is easy to show why the full tank car or drum will not explode, and by using only a few cc.'s of this material it is easy to show how dangerous solvent vapors really are. By using the explosive chamber in comparison to a drum or tank car we are able to get the employee to appreciate the fact that a real hazard exists.

It is not only necessary to see that employees use proper tools and follow out definite rules in regard to safe equipment, it is also necessary to see that they are properly informed in regard to wearing shoes with nails in them, and it is just as necessary to be sure that they understand that they must not work around solvents with rubber-soled shoes or with rubbers over their shoes.

We pay special attention to the type of instruction that is given to our truck drivers. It is necessary for these men to handle many types of hazardous materials in various kinds of containers, and they should know what will happen when different materials come in contact with each other.

All of the materials in our different plants are handled in definite sized units, and the trucks for handling these materials are of a size which will not permit the putting on of a larger quantity than it is felt safe to handle.

As an example of how much coöperation we get from this method of training employees, we have had instances where employees have prevented engineering and maintenance men from doing any work in a department until the foreman was notified, because the man on the job thought that if this work was permitted to go on it might cause a fire.

We stress housekeeping conditions and have a competent inspection force who are constantly checking throughout the plant. It is also a part of the

duty of these inspectors to talk to the foreman in regard to methods of handling materials or of any hazard which may exist in his department.

The use of open flames throughout our plants, especially in hazardous locations, must be approved by the safety department, and if it is necessary to do a job which creates a hazard all of the safety precautions possible are taken.

In regard to our inspection work, about half of the departments in our plant are inspected once a month and a written report with recommendations is made of every inspection.

One of the most important things in educational work is the discussion you get from the employees. In starting this work it was our thought that, if we could point out many of the hazards to the employees and discuss them freely, they would in turn tell us of conditions throughout the plant that created hazards of which we had no knowledge. After about four years of experience we found that this worked out very satisfactorily, so much so that employees working around any flammable materials come to the safety department once a year for a demonstration and discussion.

It is not difficult to get the employee to discuss conditions which exist in his department providing the right type of safety man is chosen to take charge of this work. This is important if you wish a plan of this kind to succeed. The first thing that must be done is to win the confidence of the men in the group. We have found that a group of from 25 to 30 is about the best number to talk to. When you exceed this number it is extremely difficult to keep them interested in the subject you wish to discuss.

Some of the very best illustrations of heat causing fires have come directly from the employees. One tells of a fire which occurred in his home when he wrapped a cloth around an electric light bulb to prevent light from shining into the eyes of one of his youngsters, who was ill. After putting the cloth around the light he left the room and upon returning about four or five minute later the cloth was burning.

Another example, which shows how dangerous flammable liquids are, was given by an employee who said that while driving his car in the winter he froze his radiator. He drove it into the garage, took off the radiator cap and put a blanket in front of the radiator, letting the motor run to thaw it out. He had some alcohol in the radiator but the quantity was not sufficient to prevent freezing. While the motor was running, he stepped to the rear of the car and lit a cigarette. There was a flash and he explained that the radiator burned like a blow torch. Before the fire department arrived the car and garage had burned.

It takes about one and one-half hours for each class, and about 3000 employees came to our safety department last year for discussion and demonstration. This takes about two months.

A great deal has been written about the uncertainty of the human element in industry, also about the gross carelessness of the individual. It has been our experience that most of the things that happen are not due to carelessness, but rather to a lack of knowledge on the part of the individual who was responsible. Some may think that there would be a tendency for employees to feel that they were working under extremely dangerous conditions if they know all of the facts. This is not true, providing the job is properly handled.

The employee who does not have a knowledge of the hazards connected with his job may get by, but the employee who has direct interest in his job and does have a knowledge of all of the hazards connected with it will be a real asset to any organization. There is one thing that must be borne in mind, and that is that safety standards for the employee must be the same as the standards for everyone else in the organization, and, of course, these standards must be based on a uniform company policy.

Plant Fire Brigade Competitions.

By George H. Greenfield (Member N.F.P.A.),
Fire Prevention Engineer, Canadian Car and Foundry Company.

Competitions involving fire department evolutions, such as hose laying and extinguishing test fires, can readily be arranged between different fire companies of an industrial plant, or if the organization has more than one plant, as an inter-plant contest. This type of competition is concerned only with the efficiency of the plant fire brigade and does not cover other features of fire safety of the plant, although with the management sponsoring plant fire department activities the chances that the conditions prepared as a whole may be fairly good.

The Canadian Car and Foundry Company and the Canadian Steel Foundries, Ltd., have had, during the past ten years, good success in a type of inter-plant competition which covers every department, including the fire brigade, fire apparatus, and the general fire safety conditions of the plant. The plan has been to hold an annual competition with the award based on a schedule of points, part of which are awarded on the basis of general plant conditions and part on the basis of the fire brigade efficiency shown at an annual inter-works fire department competition. A silver cup has been donated by the company for the works making the highest number of points. There are also

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This article is based upon an address delivered at the 35th annual meeting of the N.F.P.A., Toronto, May 11-14, 1931. The address was illustrated by motion pictures, which cannot be reproduced in the QUARTERLY. A few photographs have, however, been selected for reproduction here which illustrate some of the important points.

MARKING SCHEDULE FOR PLANT INSPECTIONS.

(The number of points given after each heading is the score for this item, subject to deductions for various deficiencies as given in the schedule.)

	Deficiency Points for Each Offense
Fire Station. 250 points.	
Missing boots, rubber coats or other minor defects	50
Shortage of extinguisher charges or other supplies	50
Untidiness in station	50
Untidiness in equipment	50
Defective records	25
Failure to record closed valves	300
Hydrants and Hose Houses. 450 points.	
Minor equipment missing	25
Hose shortage, or hose used for other than fire purposes	100
Hydrants obstructed by stock, freight cars, snow	100
General Clean Up. 1000 points.	
Woodworking shop untidy	150
Paint and varnish shop untidy	200
Waste cans defective, or not emptied daily (each can)	100
Fuel oil leakage or other defect	50 to 200
Combustible refuse outside buildings not cleaned up	100
Rubbish cars left in buildings overnight when containing material subject to spontaneous ignition	250
Power plant, general untidiness	200
Careless use of wood refuse fuel	200
Dirty pipe ducts and machinery pits	100
Store buildings, general untidiness	500
Excelsior or other loose combustible material	100
Obstruction of automatic sprinklers (each head)	25
Drafting and foremen's offices, waste paper accumulations	25
Fire hazards not otherwise specified	100
Smoking (each offense)	200
Roads. 200 points.	
Each obstruction	100
Fire Alarm Turn Out. 250 points.	
Each man short of 50% of recognized strength in one minute	25
Fire Pressure. 250 points.	
Not raising fire pressure within reasonable time	100 to 150
General Excellence. 100 points.	
Item to cover favorable items not otherwise provided for	
Maximum Number of Points Credit	2500

The Turcot Works Fire Brigade, in front of the Works Fire Station, with cup. The Turcot Works won the inter-plant contest in 1921, 1923, 1926, 1927 and 1930.

cash prizes. The cup becomes the property of the plant winning it for two years in succession. The winners since 1920 have been as follows:

1920	Dominion Works	1926	Turcot Works
1921	Turcot Works	1927	Turcot Works
1922	Longue Points	1928	Dominion Works
1923	Turcot Works	1929	Dominion Works
1924	Dominion Works	1930	Turcot Works
1925	Dominion Works		

Two inspections of each plant are made every year, one in midsummer and the other under snow conditions. The inspections are carried out by an independent outside inspector, who follows a grading schedule which has been developed with the coöperation of the Sprinklered Risk Department of the Canadian Fire Underwriters' Association. Mr. Arthur Mann of the Canadian Fire Underwriters' Association has also refereed the inter-plant fire brigade competitions since their inception.

The inspections are made without previous warning, extraordinary precautions being taken to see that no one, not even the writer, knows when one is going to take place. Experience with this system shows a very beneficial effect from the inspections, and it is very seldom that these inspections disclose conditions calling for the imposition of heavy penalties. The marking schedule, showing the points allotted to the various features, is reproduced here in condensed form. It should be noted that this schedule applies to each of the two semi-annual inspections, the total number of points awarded on the basis of inspections being the sum of the results of the two.

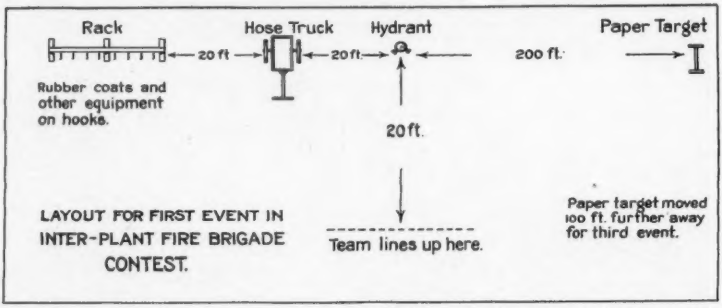


Diagram showing the arrangement of clothes rack, hose truck, hydrant and target.

The four Montreal plants of the company have fire stations operated and maintained almost exactly in accordance with the recommendations on private fire brigades developed by the N.F.P.A. Committee on Field Practice and published by the National Board of Fire Underwriters. As a matter of fact, this pamphlet was largely developed on the basis of our experience with private fire brigade organization. The equipment of the fire station, records, supplies kept, etc., are all in accordance with this pamphlet.

The annual fire brigade competition is held at some neutral point in order to avoid giving any individual team any advantage. Each works sends a team of seven men and a captain. The teams are selected by the fire chief of the individual plant. Each team is fully equipped with rubber coats, boots, helmets, belt and spanners. Each team takes its own hose truck, which is fully equipped and carries not less than 300 ft. of 2½-inch rubber lined hose.

A team on the run.

Hitting the paper target with a hose stream.

All hose is properly coupled; $1\frac{1}{8}$-inch nozzle tips are used. Hose lengths are not to exceed 51 feet when dry; stretching of hose under pressure is not counted. All apparatus is inspected by the referees prior to the beginning of the competition, and after inspection the teams are not allowed to rearrange hose or touch the apparatus.

The equipment is arranged as shown by the accompanying diagram. The rack has eight hooks six feet above the ground to accommodate coats, helmets, belt and spanners. Boots are placed in front of the rack. The team and the captain line up at the point shown on the diagram, fully dressed in their street clothes. At the signal the team proceeds to the rack and each man puts on his coat and other equipment. No man is allowed to proceed with the hose truck until he is fully equipped.

The evolutions consist of attaching the hose to the hydrant, stretching 150 feet of hose, taking the hose from the truck, attaching nozzle, turning on the water and hitting a paper target which is 200 feet from the hydrant. The team which breaks the paper target in the shortest time is the winner.

A second evolution with the above layout of hose on the ground consists in turning on the water, hitting the target, then assuming that the middle length of hose bursts. The middle length is taken out, a spare length taken from the truck and inserted, the water turned on and the target again hit. Here again the team completing the evolution in the shortest possible time is the winner.

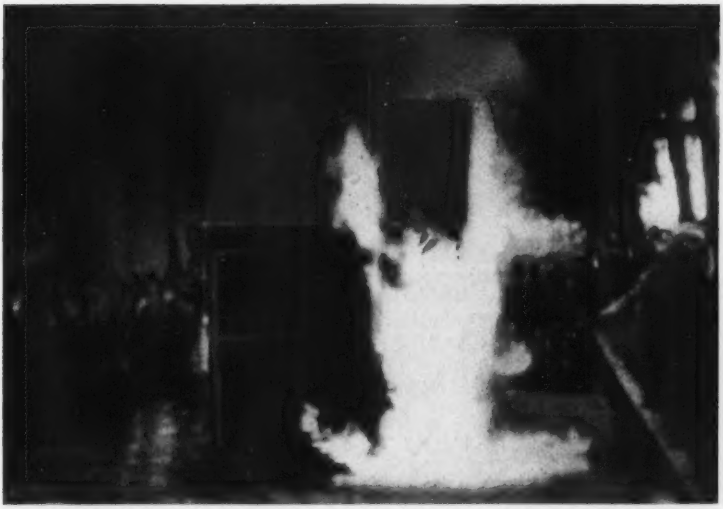
A third evolution, similarly arranged, is to uncouple, take forward the first length of hose, insert an additional 100 feet and hit the target placed 300 feet from the hydrant.

This event of the contest simulates fighting a fire behind a partition. The contestants use fire axes to make holes through the wooden barriers, and direct a 2½-gallon soda-acid extinguisher through the hole upon a fire.

The team work is supplemented by competition with extinguishers, one man representing each team in this part of the contest. The contest simulates attacking a fire behind a partition. A slightly inclined section of wall is provided for each man, consisting of a wooden frame 6 ft. by 6 ft., with two pieces of studding spaced two feet apart and sheathed with 1-inch lumber. Behind the wall is a fire built of ten pounds of excelsior and one pint of gasoline, placed six feet behind the wall. The competitors line up 20 feet away, each with a 2½-gallon soda-acid extinguisher and a fire axe weighing not over six pounds. On the signal, the men proceed to the walls, chop holes through and extinguish the fire through the holes so cut. The time of extinguishment of the fire determines the winner. A similar test is then conducted for representatives of the office fire brigades.

Special Demonstrations.

After the speed tests are run off, there is a period in which any plant may put on a demonstration of any individual feature of their work. This may consist of a life-saving demonstration and resuscitation, operation of a foam generator, the use of carbon dioxide extinguishers, use of smoke masks, or other special equipment. These special demonstrations, arranged at the discretion of the individual competing plant fire brigade, if judged by the referees to be good, add 150 points to the score of the team.



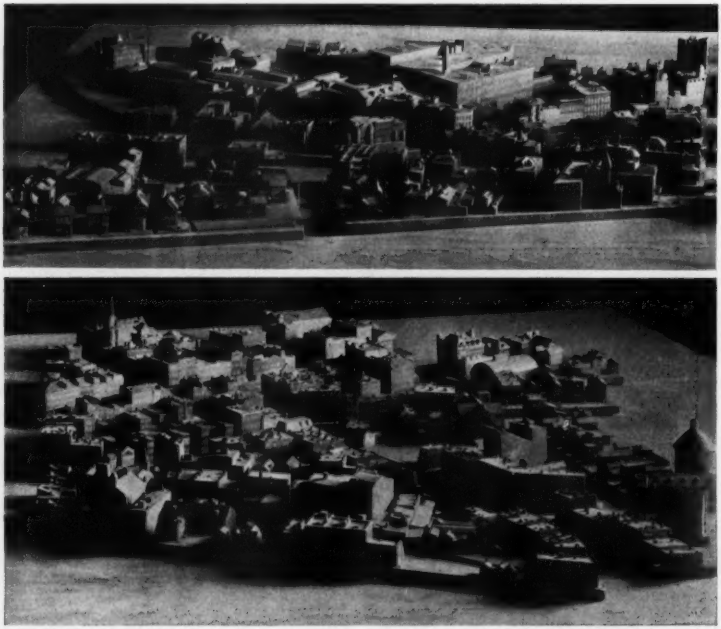
A model house, used for a special demonstration of fire extinguishing.

The fire brigade hose laying and extinguisher items give a total score of 1,000 points, divided among the different events as follows:

Dressing, stretching hose and hitting target 200 ft. from hydrant.....200 points
Changing middle length of hose and again hitting target.....300 points
Adding 100 ft. of hose and hitting target 300 ft. from hydrant.....350 points
Using fire extinguisher through hole in wooden partition.....150 points

In addition, the demonstration of some special feature may give an added credit of 150 points. A further credit of 100 points is given teams showing good discipline. A penalty of 150 points is imposed on any team violating the rules of the contest or showing any unfair practice, the penalty being repeated for each offense. Loss of tools or parts of the equipment involves a penalty of 50 points for each item lost on the run.

The schedule of credits and deficiencies is so arranged that the entire plant participates in the contest. No matter how excellent a fire brigade a plant may have, if the housekeeping is not good in the plant the points of deficiency may more than offset the credits won by the team in the annual competition. Our experience with this plan has shown that it not only stimulates the morale of the plant fire brigade, but it maintains an interest in fire prevention among all our employees and has been a constructive influence towards minimizing fire losses during the past ten years.



The congested section of Auburn, N. Y., in miniature, constructed by the firemen.

Fire Fighting Strategy in Auburn, N. Y.

Many city fire departments in recent years have recognized the fact that efficient and successful attack on fire requires a thorough advance knowledge of the buildings in which the fires are occurring. Not only is it necessary to be acquainted with the structural features of buildings which would contribute to the rapid spread of fire, but it is important to study the possible avenues of approach which afford ready access to the seat of the fire. Moreover, the collective efficiency and team-work of each unit of a fire department depend a great deal on how much of this information is common knowledge to each individual member of the unit and on how thoroughly each man understands the particular function he is to perform at a fire in a specific building or group of buildings.

The question is often raised of how this information can best be acquired and assembled for purposes of instruction and developing the most effective use of equipment and men at possible fires in particular locations. The Auburn, N. Y., Fire Department has solved this need in a most ingenious and

satisfactory way. The members of the department have created in their spare time a complete model replica of the congested section of the city contained within the fire limits. The small scale copies of each building were cut out of solid blocks of wood and assembled in proper position in the general layout. Black paint was used to indicate all of the exterior openings, such as windows, doors and skylights. Other colored paints denote the type of construction, such as brick, stone or frame. Nails represent the position of hydrants and hose connections to sprinkler systems and standpipes on the roofs. Other features of value to fire fighting which are shown include fire escapes, fire wall parapets, roof hatches and elevator pent-houses.

Individual blocks and buildings may be detached from the complete model for study of specific hazards.

This layout has been of tremendous value to the firemen in Auburn in properly visualizing their duties. Regular weekly classes of each fire company have been held, with company officers acting as instructors. Using the model for illustration, imaginary fires have been fought in the various locations and the best methods of attack in each building determined. In this way it is possible to determine such points as the accessibility of all sides of a building, where hose should be laid and advanced, opportunities for raising ladders and carrying them through buildings, locations for ventilating a fire, etc. Thus much valuable time may be saved at actual fires, and wrong decisions, often caused by necessary haste, are eliminated.

The larger view of a particular block illustrates even more clearly the value of the model. Completely surrounded on all sides by a solid wall of buildings, there are no alleys or other open areaways affording access to the center of this block. The difficulties which would be encountered in fighting fire or performing rescue work at the rear of any of the buildings in this block are obvious. A little study by the firemen revealed that only a single place on the first floor of one of the buildings affords a direct route to the

center of the block adequate in size and properly located to permit ladders of any length to be carried through and raised.

Other cities might well profit by the example of industry and interest in the perfection of its work which the fire department of Auburn has shown in the making and use of this model plan.

Radio Transmitting Hazard.

By K. W. Keene.*

Following the example of progress in so many other branches of engineering, development of the field of radio communication has recently disclosed a fire hazard which has as yet received little attention. Fortunately, it is a hazard which may easily be eliminated by careful planning.

While operating a transmitter at a private radio transmitting station, continuous extraneous sparkings, during operating periods, were noticed in rooms containing and adjacent to the transmitter apparatus. The sparks were characteristic of high frequency, small energy discharges, and were occurring between sprinkler piping and unused service piping and between steel electrical conduit and a roof leader. All pipes were grounded. The ceilings in the vicinity of the transmitting apparatus were well covered with conduit and sprinkler piping, and close to this piping the antenna lead-in passed.

To eliminate the fire hazard caused by the sparking, unused piping was removed; and a copper, non-magnetic grounding system was provided for all remaining piping. The main grounding conductor, which led to the basement and ground, consisted of copper straps more than one inch wide, and the branch conductors, connecting frequently to the piping systems, consisted of smaller copper straps.

As an explanation of the sparking, it has been found, and can be shown mathematically, that, if metal structural work of a building, water or sprinkler piping or electrical conduit is located close to a transmitter, there can be induced in any of these conducting materials sufficient high-frequency electrical energy to cause sparking to other near-by conductors, even though both conductors between which the spark exists are grounded at a distant point. In installing radio circuits in transmitting stations, therefore, it will be well to remember that such circuits should be kept well away from near-by conducting materials, or else these materials should be grounded via a low impedance path. The fire hazard of sparking will then be eliminated.

*Extract from article "Extraneous Sparking from Radio Transmitters," in May issue of *Laboratories Data*, published by Underwriters' Laboratories (Member N.F.P.A.).

The Federal Fire Council.

The Federal Fire Council is an informal inter-departmental organization of the U. S. Government, functioning in an informative and advisory capacity to the various government departments. The fire record of government buildings in Washington has been good; for the seven years ending January 1, 1930, in the buildings under the jurisdiction of the Protection Division of the Public Buildings and Parks, there were 347 fires, with an average loss per fire of only $3.70. However, the fires in the Executive Offices of the White House and in the Capitol Building (QUARTERLY, January, 1930, pages 214 and 229) focused attention upon the fire problem of government property and particularly upon the records, museum collections, paintings and other priceless and irreplaceable material subject to destruction by fire. In April, 1930, at a meeting of representatives of government departments and establishments, the Federal Fire Council was organized. The Council, while largely composed of men who had not previously been specializing in the fire protection field, has maintained close contact with the N.F.P.A. through Mr. S. H. Ingberg of the Bureau of Standards, U. S. Department of Commerce, Chairman of the N.F.P.A. Committee on Protection of Records, Secretary of the Council, and Dr. David J. Price of the Bureau of Chemistry and Soils, U. S. Department of Agriculture, member of the N.F.P.A. Board of Directors and Chairman of the N.F.P.A. Committees on Dust Explosion Hazards and Farm Fire Protection, who has likewise been an active member of the Council.

Included in the scope of the Federal Fire Council are the formulation of recommended standards or policies relating to such items as exit requirements for buildings, protection of records, elimination of fire hazards, fire detecting and extinguishing equipment, and fire alarm and patrol service, unless already covered by interdepartmental agencies. The activities of the organization are conducted mainly through committees concerned, respectively, with fire hazards, apparatus, and appliances, and coördination of inspection within the different departments and establishments.

The Committee on Apparatus and Appliances assists the Fire Hazards Committee in its inspection projects on matters pertaining to needed fire-protection equipment. Its six subcommittees are also preparing material descriptive of the different types of fire protective devices, such as manual fire extinguishers, permanently installed fire extinguishing systems, fire alarm equipment, motor driven fire apparatus and pumps, protection for openings, and office furniture and equipment. This includes definitions of the useful scope of application and effectiveness of the devices concerned, together with approximate estimates of cost.

The Committee on Inspection and Interdepartmental Coöperation serves as a contact medium between agencies in the government that are concerned with the fire hazard and assists in establishing such agencies where none now exist. At its organization meeting it was decided to obtain estimates of the amount, kind, and value of government property subject to loss by fire, and information on protection measures taken. An inspection manual that will contain essential information on fire hazards and protection methods is being prepared for the use of the inspection groups.

On request of government officials concerned, inspections are made of government buildings and institutions, and recommendations made with respect to the design and occupancy of new buildings. These activities are carried on by committees, which have accomplished a great deal in the short space of a year and a half, but which are necessarily limited by the limited time that can be devoted to the Federal Fire Council work by the members, all of whom hold important and responsible positions in their respective departments. For this reason the work of the Council committees has been limited to buildings in the District of Columbia.

A comprehensive fire hazard survey of all Federal prisons, with recommendations for the protection of existing buildings and advice on the design of new prison construction, was requested by the Bureau of Prisons, U. S. Department of Justice, in the fall of 1930. With prison properties scattered throughout the United States this survey was a major undertaking. The National Fire Protection Association, through its Field Engineering Department, offered to undertake this survey, which has been in progress for nearly a year. The Bureau of Prisons has assumed a portion of the expenses of this work. Comprehensive reports on each institution, prepared by the N.F.P.A. Field Engineering Department, have been presented at meetings of the Council, and transmitted to the Bureau of Prisons with recommendations. Measures taken as a result of these surveys already show a marked effect in increased fire safety of Federal prisons, and a comprehensive fire protection program is rapidly being put into effect.

The quarterly meetings of the Council furnish a forum for the discussion of governmental fire prevention policy, which has been of great value to all departments concerned. At these meetings reports of the committees are presented and acted upon, and information presented upon the special fire problems encountered and fire protection methods employed by the various departments. The character of these meetings is indicated by the following extract from an article on the Federal Fire Council, published in the *Technical News Bulletin* of the Bureau of Standards, March, 1931.

Three quarterly meetings have been held at which reports of committees and other items of interest have been presented. An interesting report on the institutions under the Board of Public Welfare of the District of Columbia was presented at the June meeting.

At the October meeting a report on the Patent Office, as it will be in the new Commerce Building, was presented by the Fire Hazards Committee. The officials of the Patent Office are making every effort to safeguard the valuable records, library, and data under their care, as a serious fire might easily be a calamity to the commercial world. The new Commerce Building is of fire-resistive construction with a minimum amount of combustible interior trim. Attention has been given to the prevention of spread of fire from floor to floor by enclosure of openings, and floor areas have also been subdivided by suitable partitions and doors. For several years the Patent Office has been working out a program of replacement of wooden filing cases, book stacks and furniture with metal equipment. This program is well under way, and it is expected that by the time the office moves into its new quarters in December, 1931, a large proportion of its occupancy will be so equipped.

At the same meeting the matter of protection for the book stacks in the new annex to be built for the Library of Congress was discussed. The book stacks in the present building are open from top to bottom, and a fire originating anywhere within the stacks would spread rapidly. In the new design, considerations are given to the possibility of providing fire stops at each stack level and maintaining smaller undivided areas than with the present stacks.

The general protection afforded books and records by the type of furniture and shelving used was discussed, and results of fire tests conducted at the National Bureau of Standards with office and record storage occupancy were presented.

At the recent January meeting a further report was presented on a Federal correctional institution in the District of Columbia, and representatives from the War and Navy Departments gave an account of fire prevention and protection activities within these departments.

The fire prevention section of the office of the Quartermaster General is charged with the protection of property valued in excess of $1,600,000,000. Purchases of fire protection equipment are made on one proposal, to secure more advantageous prices and uniform equipment. Plans for new construction are reviewed and drawings and specifications prepared for any new fire protection equipment or water supplies that may be needed. Much progress has been made in the standardization of fire fighting equipment, including the adoption of the national standard hose coupling thread and a single design for pumping equipment mounted on the Army standard truck chassis.

The fire prevention activities of the Navy Department divide themselves into two main divisions—those for land establishments and those for ships. The men afloat are made familiar with the fire hazards and methods of prevention and extinguishment common to ships by means of lectures, slide films, and drills, fire prevention being a subject in which a man must be proficient in order to be eligible for promotion.

In shore establishments special attention is given to housekeeping and watchman service. All shops and buildings are cleared of waste material and débris at the close of each day. Shore stations are equipped with modern fire fighting equipment, and in addition each shop has its own organization that answers fire calls within the shop, using hand fire extinguishers and similar equipment until the arrival of the regular fire fighting force.

As an indication of the effectiveness of the Navy's fire prevention and protection work on about $600,000,000 worth of land property, there has been an average annual loss of only $35,000, or 6/1000 of 1 per cent, over a period of three years. The per capita loss as figured on the number of employees is 60 cents, as compared with the nation's fire loss of over $3 per capita.

At the April and June, 1931, meetings of the council a large number of valuable reports were presented, in addition to the previously mentioned

reports on penal institutions. At the April meeting a report was made on the Capitol building, for the protection of which $100,000 was appropriated at the last session of Congress, and on the National Training School for Boys. The fire protection methods of the U. S. Veterans administration and of the Office of Public Buildings and Public Parks were described, and progress reports made on various pending items. At the June meeting a survey was presented of the occupancies of the Department of Commerce as a part of the project of obtaining estimates of value and types of government property subject to fire loss and information on protection. A comprehensive report on the Smithsonian Institute was presented, with detailed recommendations for modernization of this group in the interest of fire safety. Other items discussed included fire alarm systems as applied to various types of buildings, the new National Archives Building, the general Federal building program, the equipment of buildings and related items.

Contacts between those concerned with the care of property in the different departments are helpful in introducing the most effective methods of prevention and protection. In conjunction with the general work of the organization, it will aid in securing the application of sound, conservative principles. The group concerned recognizes that the complete elimination of possibility of fire is generally out of question, but a large percentage of fires originating from poor structural, maintenance and housekeeping conditions can be prevented, and the destructiveness of such fires as do occur can be greatly reduced by proper recognition of hazards and application of the most effective means of prevention, detection, and extinguishment. Such good fortune as the government has had in avoiding serious fire losses may be attributed largely to good construction, good housekeeping, absence of moral hazard, and a limited amount of fire protection equipment maintained in good condition. Extension and more general application of this practice, with further elimination of unnecessary hazards introduced by interior finish and equipment of buildings, should aid in further decreasing the fire loss on buildings, many of monumental type, on records, works of art, and other building contents that are irreplaceable or of high monetary or historic value.

Hose Coupling Standardization in Canada.

By B. Stuart McKenzie,
Secretary, Canadian Engineering Standards Association.

The standardization of fire hose couplings in Canada, which is one of the projects of the Canadian Engineering Standards Association, presents unusual difficulties owing to the wide divergence in dimensions of couplings now in use in different parts of the Dominion. Securing the universal acceptance of a Canadian standard is apparently an even greater problem than was encountered when fire hose coupling standardization was initiated in the United States thirty or more years ago. Thus far no all-Canadian standard has been evolved. The work of standardization should have been done long ago; now the problem is much more difficult.

The trouble in Canada is that there is a greater variation in the outside diameter of the hose connections than in the United States, which makes it very difficult indeed to get agreement, the range in outside diameter of male couplings being 3 inches to 3-31/64 inches. Another feature is that in some parts of the country, particularly where the temperatures in winter are very low, fire department authorities favor a standard of five threads to the inch instead of 7½, as they claim it is easier to make connections with the coarser thread. Some of the cities near the border, however, favor the 7½ threads to the inch, as this would enable them to secure assistance from municipalities over the border. In the Western Provinces, a standard proposed by the Western Canada Fire Underwriters Association has been almost universally adopted, this standard being for a 2½-inch hose, outside diameter 3¼ inches, and six threads to the inch. In the Province of Nova Scotia, a zoning system has been established under a provincial law, approving 5, 7 and 8 threads to the inch for 2½-inch hose couplings.

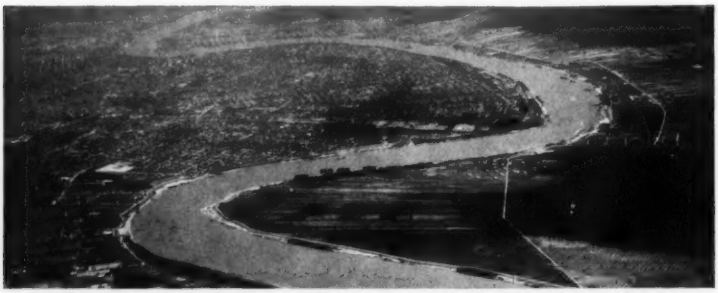
In Canada there has been the same trouble due to lack of interchangeable hose couplings as was formerly experienced in the States. In many cases neighboring municipalities have been unable to aid cities in which serious fires have occurred. A notable instance was the conflagration in Toronto a good many years ago, when the fire brigade of Hamilton sent apparatus which could not be used and the Toronto fire chief worked all night in an endeavor to make an emergency adapter, but without success. In the fire at the Chateau Frontenac at Quebec in January, 1926, Montreal sent fire apparatus on a special train to Quebec, but could not connect up to the local system.

Suggestions have been made at various times for the use of adapters, and samples have been submitted at several conventions of the Canadian Section

of the American Water Works Association, but thus far nothing definite has been accomplished. Under present circumstances it would appear almost impossible to get a standard which could be universally adopted throughout Canada, but the Canadian Engineering Standards Association has been collecting as much information on the situation as possible with a view to bringing this matter up for active consideration at some future time.

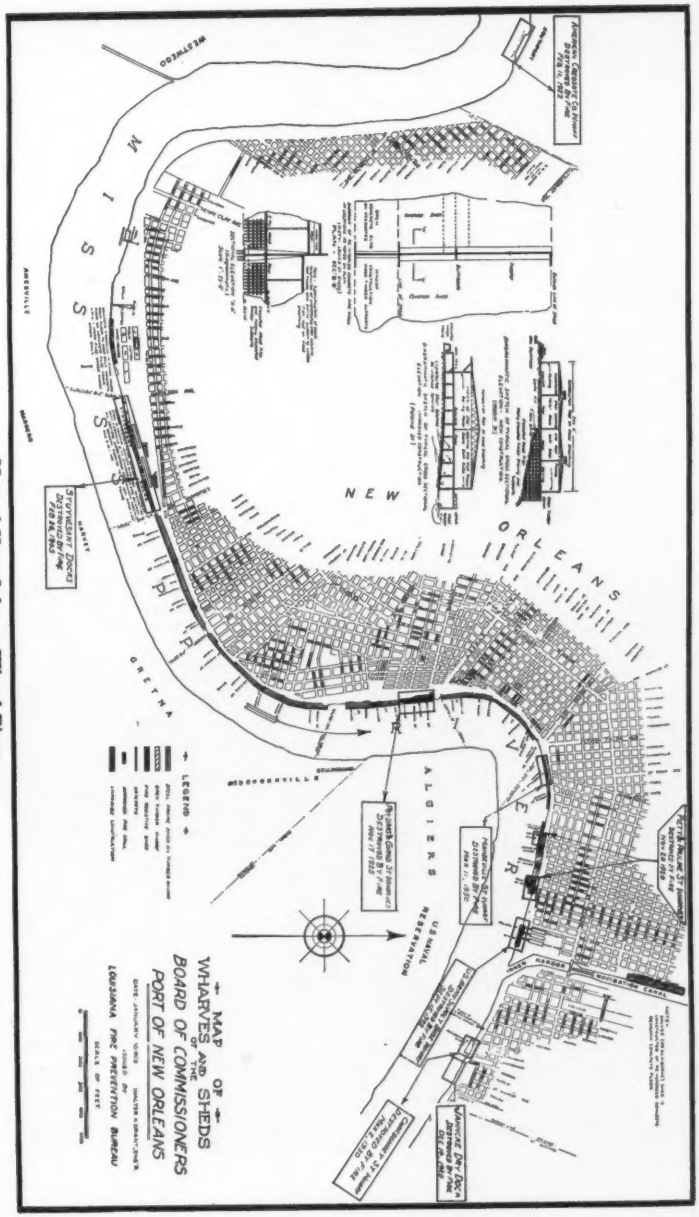
The Protection of the New Orleans Wharves.

The protection of the New Orleans waterfront presents an unusual problem in fire protection which has been solved this year. Eight miles of wharves along the levee, filled with cotton and other combustible contents, resting upon a wooden substructure, and with practically no break, have for years involved a hazard of serious losses. The fire loss on these New Orleans waterfront properties prior to 1931 has averaged well over a million dollars a year for a considerable period. The accompanying map shows the location and extent of various large waterfront fires. These fires have been reported in the QUARTERLY from time to time, and with this article selected views of these fires are reproduced from former issues of the QUARTERLY.

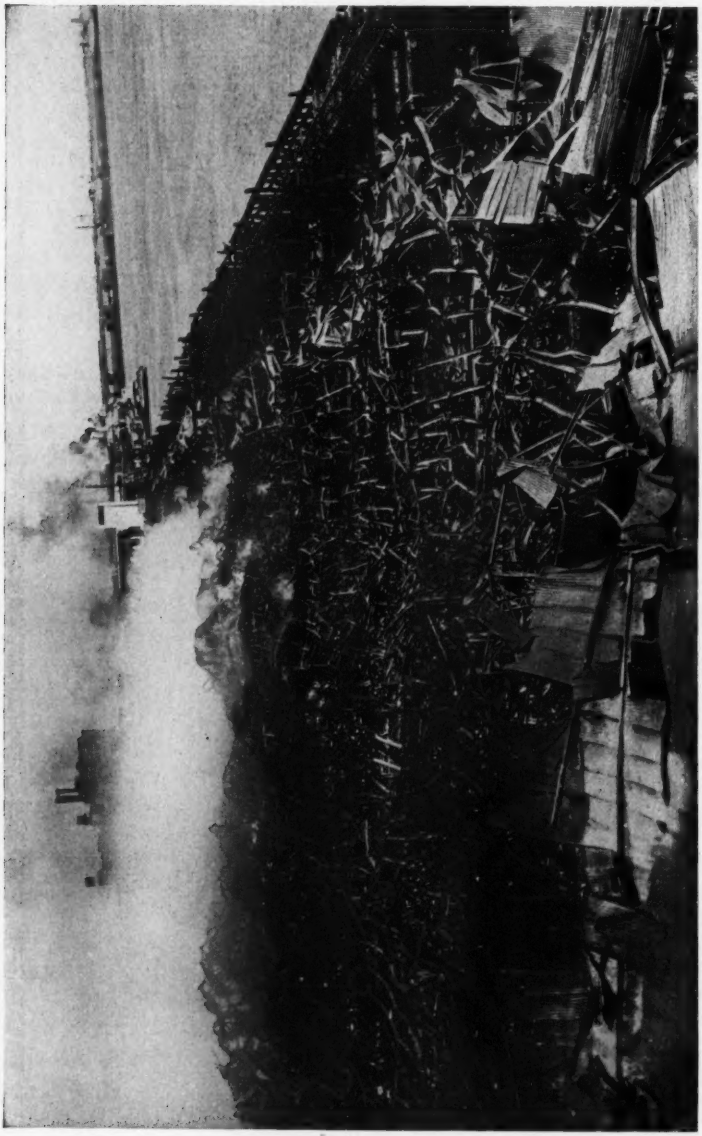


Air view of the Port of New Orleans, looking down the Mississippi River, with the City of New Orleans on the left bank. The wharves are in the middle background.

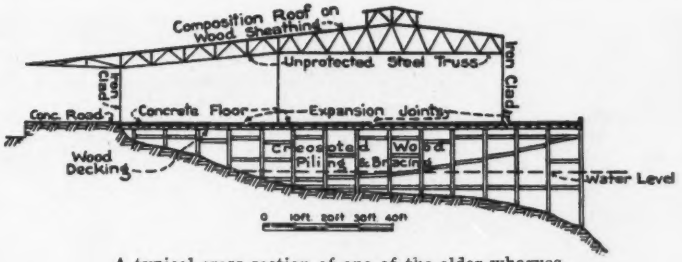
The New Orleans wharves, with the exception of some railroad property, are practically all under the control of the New Orleans Dock Board (Board of Commissioners of the Port of New Orleans). The Dock Board has by no means ignored the fire hazard, and through a period of years has been applying various measures that are generally recognized for the protection of waterfront properties. Fire boats have been stationed along the river; large water mains with good pressure have been laid just back of the waterfront; first aid devices, watchman service and like features have all been given attention. While these features of protection have demonstrated their value, they have not sufficed to prevent serious losses.



Map of New Orleans Wharf Fires.



A portion of the ruins of the fire of November 17, 1925, where 1300 ft. of wharf sheds were destroyed with a loss of $4,000,000.

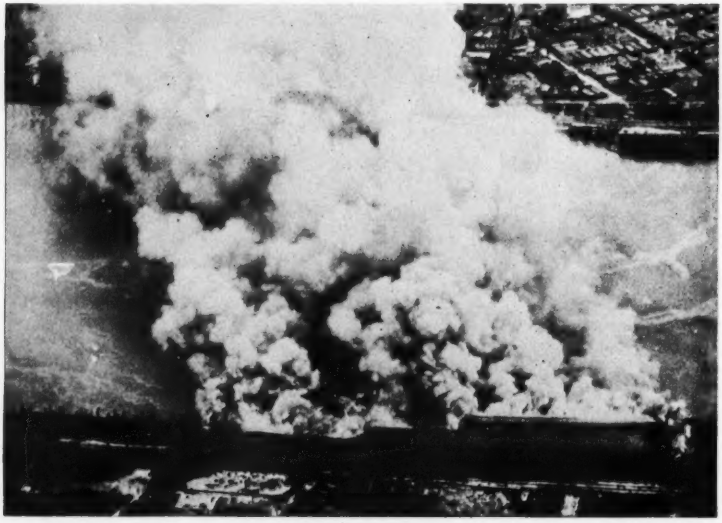


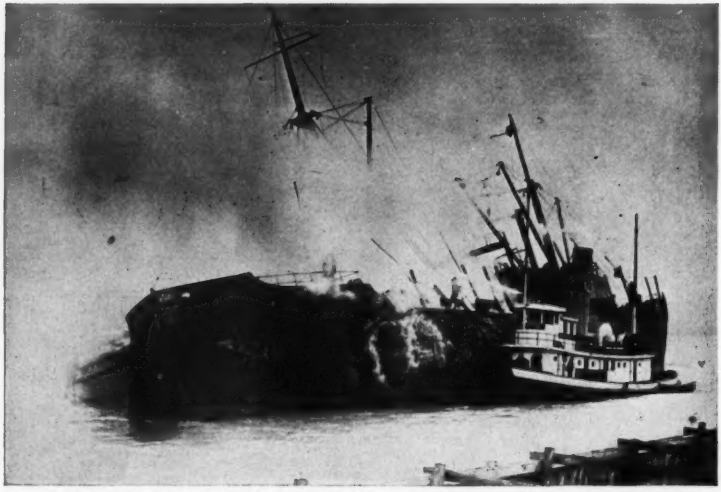
A typical cross-section of one of the older wharves.

The large area wharf sheds, filled with cotton and other combustible commodities, present a serious hazard. Except in a few cases where automatic sprinkler protection has been provided, fire starting in one of these sheds generally has flashed over the cotton and involved the entire structure almost before the fire department could be summoned. The problem presented here has been similar to that of any large area structure with flammable contents, where any fire, unless extinguished in its very incipiency, means heavy or total loss to the structure of origin, and fire department operations may be of little value except to protect adjoining structures.

There has been, however, one vital difference between the New Orleans wharf sheds and ordinary buildings of similar size and occupancy, in that the New Orleans wharf sheds have been built on wooden foundations, with large open spaces under the wharf deck. These spaces, filled with wooden piling and cross-braces, inaccessible for fire fighting and extending without breaks for distances of a mile or more along the waterfront, have been the major factor in the spread of New Orleans waterfront conflagrations. Once a fire starts in one of these spaces it has been practically impossible to control it, despite the best efforts of an efficient fire fighting force. These spaces act as horizontal flues and, under the influence of a strong wind, fires spread through them with great rapidity, and it has generally been impossible to stop the fire until it reached some break in the wharves or other open space. The losses have been tremendous and have involved not only the wharves and the valuable cargoes stored on them, but also have often involved the vessels moored at the wharves. So rapid has been the spread of fire that it has sometimes been impossible to get the vessels away in time to avoid destruction.

The wharves are practically all of creosoted timber construction. Such creosoted timber structures are difficult to ignite because the temperature must reach the vaporization point of the preservative material before ignition can take place. However, once high temperatures are reached a gas is formed which ignites and results in a fire of intense heat which travels at an increasing rate as the increasing heat distills off and ignites greater quantities of gas.





Two views of the fire of March 11, 1930. The upper picture shows the furious burning of the Mandeville Street Wharf, with the fire rapidly spreading through the under-dock space beyond the reach of the fire department. The offshore wind carried the fire to two steamships moored at the wharf, and handicapped fireboat operations. The lower picture shows the S.S. Munaires, which suffered damage of half a million dollars. The total loss, including wharf, sheds, cargo and vessels, was more than two million dollars.

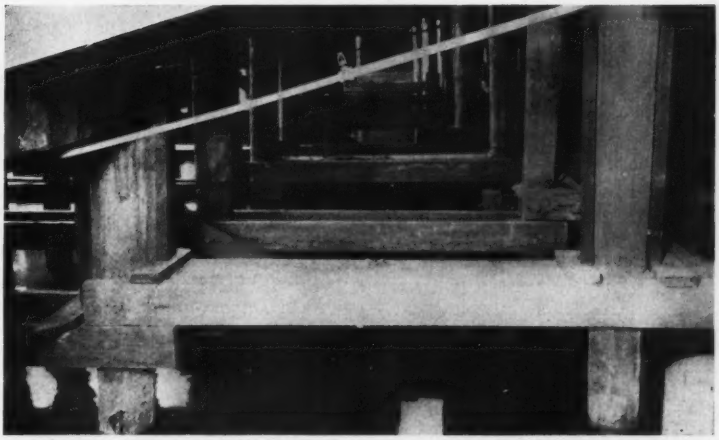
The usual solution of a problem of this kind would be the use of concrete piles or some other non-combustible substructure, or the subdivision of the areas by fire walls at reasonable intervals, but with the special conditions obtaining on the banks of the Mississippi River neither of these methods has been generally employed. Non-combustible substructures have been used for a few of the newer wharves, but with the soft bottom conditions under the levees, wooden piling has been generally used as the most practicable type of construction. Until recently fire walls have been considered out of the question, for the building of fire walls, which would be across the current, might have disastrous effects at high water, resulting in serious undermining of the structure or building up of sand bars to obstruct navigation. Experience has shown along the banks of the Mississippi that the natural flow of the river cannot be impeded without serious results. The present form of construction of the wharves has been used because this offers a minimum of obstruction to the flow of the river. However, the conflagration hazard became so great that the port authorities decided to risk the lesser hazard of shifting banks, and embarked on a program of placing a limited number of specially designed reinforced concrete fire walls. There are now fifteen of these walls, the average spacing being about one quarter mile.

Conditions at New Orleans are peculiar in respect to the very large range between high and low water level, which far exceeds the maximum tide range at any other port in the United States. This means that at the low water stages of the river a great height of combustible piling is exposed. Another feature where New Orleans is different from the ordinary port is in the continuity of the wharves along the waterfront. The usual port construction consists of piers extending out into a harbor. The individual piers in such cases may present severe fire hazards and difficulty in fire fighting, so that a fire once started will involve the whole pier. The waterfront, however, is broken up into individual piers with open slips between which afford some opportunity for stopping the spread of the fire along the waterfront. In the case of New Orleans the wharves are practically continuous, being built parallel to the river along the levee for practically the entire waterfront of the city.

As the disastrous fire record continued it became increasingly evident that if the Port of New Orleans was not to suffer loss of traffic and prestige because of the undue fire hazard, some effective measures should be taken. After protracted consideration a comprehensive program was finally undertaken and brought to completion during the present year by the New Orleans Dock Board. The Louisiana Rating and Fire Prevention Bureau (Member N.F.P.A.) was the guiding influence in bringing this development about and coöperated in all its details. The plan followed consists, in addition to other recognized forms of protection, in complete automatic sprinkler protection

A typical view of the under-dock space, where complete automatic sprinkler protection has been installed.

One of the 6-in. thick wooden bulkheads that divide the under-dock space. With an automatic water curtain on each side, these bulkheads take the place of fire walls.



Another under-dock view, showing wooden piling and cross-bracing, with recently installed sprinkler line.

not only for the pier sheds and other buildings above the wharf deck level, but for the entire under-deck space. The installation just completed is probably the largest single sprinkler installation in the world, with a total of 112,478 sprinkler heads used. In view of the desirability of sensitiveness and minimum liability to corrosion, quartz bulb heads were installed.

The desirability of sensitiveness is due to the burning characteristics of the creosoted timber mentioned previously. If water can be applied with sufficient promptness to stop the generation of gases the fire should be extinguished very promptly, as there is practically no combustible material other than the creosoted timbers underneath the wharves. The corrosion problem is more serious than in buildings because of the severe conditions; during the flood periods the sprinklers will be inaccessible for inspection, and will be subject to continuous moisture and possible submersion.

Automatic sprinkler protection for the under-deck space, while going a long way towards solving the problem, was not felt to be sufficient without some sort of subdivision of the miles of combustible substructure. As previously noted, fire walls are few and far between, but an arrangement of automatic water curtains at intervals was designed to limit the spread of an under-deck fire. These consist of substantial wooden bulkheads extending down about twenty feet from the pier deck with a line of open sprinkler heads on each side controlled by an automatic rate-of-rise thermostatic device. At high water this bulkhead will furnish a definite draft stop, and when wet by the open sprinklers on both sides should prevent any passage of fire. At low water this bulkhead will be slightly above the water level, but then will act as a curtain board to bank the heat, and with the operation of the heavy water

curtain on both sides it is felt will surely stop the progress of any fire which may travel faster than the automatic sprinkler heads will operate.

The sprinkler installation in these large sheds and under-dock areas was simplified by the fact that climatic conditions permit the use of wet-pipe systems. In the under-dock space the curtain boards and deluge systems are installed at intervals of from 250 to 500 feet. The large sheds, where not subdivided by other means, are equipped with curtain boards extending down from the roof at intervals of approximately 150 feet. A large water supply is required for this installation and is obtained from the large city mains which parallel the waterfront. With a direct pumping municipal system giving an adequate water supply at good pressure, a single supply was considered adequate for the sprinkler system. Fire department hose connections are provided for an emergency secondary supply.

The fire protection program of this waterfront property does not stop with the installation of automatic sprinklers. A complete organization has been formed for maintenance of the sprinklers. In addition to the regular inspections of the equipment and a routine checking of valves by watchmen, a permanent organization will be maintained to service the sprinkler equipment, and at least one man will be continuously on duty. The installation of central station supervisory service is also under consideration.

In addition to automatic sprinklers various other forms of protection are provided. A standpipe system covers all the wharf sheds with hose connections, arranged in accordance with the N.F.P.A. recommendations. Outside hydrants on the land side are spaced from 250 to 300 feet apart. Hydrant houses located inside the sheds in close proximity are provided with standard equipment, including 250 to 300 feet of one-inch hose, 150 feet of one and one-half inch hose, and standard foam and carbon tetrachloride extinguishers. Throughout the wharves there is a good supply of water casks and pails. Watch service is maintained both day and night, the night watch service being under central station supervision.

Through this installation it is felt that the hazard of the New Orleans waterfront has been practically eliminated, and from being one of the most hazardous of ports from the fire hazard standpoint it is now one of the safest. New Orleans should reap a rich reward from her forethought in reduced fire losses, and in continuity of operation of her shipping and the industries dependent upon it.

Steel Joist Floor Construction.

By Rudolph P. Miller,
(Member N.F.P.A.).

The introduction of new materials or new forms of construction in building construction seldom, if ever, runs a smooth and unobstructed course. Conservatism in the building industry and the antagonism of the makers and promoters of established competitive materials are some of the obstacles that must be overcome. Not the least of these hindrances, frequently, are the inordinate claims of the originator of the merits and revolutionary possibilities of the material or construction, and the excessive zeal of the promoter or salesman to displace existing, acceptable and tested practice. These latter misconceptions undoubtedly have been the cause of delay in the general acceptance and use of desirable developments in the building industry. The steel joist industry, among others, has, to some extent, suffered from these drawbacks, and the general public has been deprived unnecessarily, at least for a time, of the benefits of a useful and economical type of floor construction that is well adapted, in its more recent improved form, for buildings of light occupancy, more especially buildings, or those parts of buildings, which are used for residential, office or institutional purposes.

Status of the Steel Joist Industry.

Referring to this particular product, the steel joist, the Bulletin of the National Builders' Supply Association, in 1929, after pointing out the handicaps that most newly developed materials encounter, among them imitators who are not overscrupulous, frequently skimping in thickness and weight, comments that "it behooves the light structural steel men, who are just beginning to break into the firesafe residential construction field, to be absolutely sure that all the materials offered in their particular line are up to the full requirements of all standards set and recognized." It further remarks that "where there is a failure [and there have been such in steel joist construction] or an unsatisfactory performance by any material, the result is reflected instantly upon the entire line as much as it condemns the particular offending unit. The public doesn't stop to distinguish between materials. It rates them all in one category, and accepts them or rejects them as a class." Another phase of conservatism is illustrated by the remarks of the late William C. Robinson, of Underwriters' Laboratories, before the Building Officials' Conference at its meeting in 1920, when he said, "When I first looked at metal lumber, I am frank to say that it looked pretty light and

insecure. I had the rolled sections in my mind, and I had seen the action of those beams under fire, and in construction, and the light sections did not appeal to me." But he added: "In all cases you must consider a material or construction in relation to the service it has to perform, and if it performs that service properly you are bound to recognize it if you are a fair man." It is the purpose of this paper to review the present status of the steel joist industry that some judgment may be formed of the extent to which this comparatively new product fills a want in building construction.

Confidence Established by the Steel Joist Institute.

Justification for the reference to "this comparatively new product" is to be found in the fact that, in spite of earlier use and development, it is only since 1928, when the Steel Joist Institute was organized and Frank Burton, former commissioner of buildings in Detroit, was retained as consulting engineer, that confidence in the product really can be said to have been established. Previously much uncertainty was felt by the building public. Building officials hesitated, when they did not actually refuse, to permit this new form of construction, basing their actions on accidents during construction; some of them due to neglect of ordinary precautions in erection resulting in displacement of the joists on the supports and, in some instances, dropping the joists; and some due to failure to install the necessary bridging or lateral supports to prevent these light members from tilting or distorting. A serious case was one in which a test load fell, carrying with it four floors below; a careful examination of the unaffected parts revealed many broken welds. A manufacturer who sought an official approval of his assembly as fire-resistive attempted to construct in a manner that did not conform to the construction as tested. The cracking of the floor slabs over the top of the joists, due to inadequate reinforcement or insufficient thickness of concrete, was the source of many complaints. One case is reported of a building erected in 1924 in which there was considerable sagging of the floors and cracking of the ceilings underneath, though the floor loads were those of an ordinary office occupancy; it is quite likely that an unduly high load capacity claimed for the joists was responsible. Some of the earlier trade catalogues rated the strength of joists from 10 to 20 per cent higher than load tests justified. It is not surprising then that there has been considerable mistrust of steel joist construction. Each case is subject to explanation; but the public does not reason, it condemns. These troubles have, however, led to reforms in the manufacture and installation of steel joists.

Earliest Use of Steel Joists.

The use, in 1885, in the building of the State of New York Bank, in New York City, is said to be the earliest example of what might be termed a steel joist. "Steel sheets were bent to flat curves, and riveted back to back with

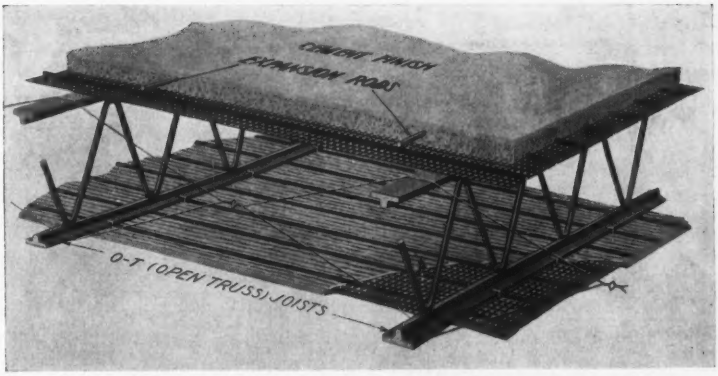


Fig. 1. General assembly of a typical steel joist floor construction.

flat top and bottom flanges." Similar members were later used, up to 1893, in Chicago, Minneapolis, and St. Louis. But these were only occasional instances. Manufacture on a commercial basis started about 1908, when the Berger Manufacturing Company marketed joists, but only up to ten feet in length, consisting of steel sheets pressed into the shape of channels riveted together to form an I-beam. In 1914 the Truscon Steel Company made similar beams by riveting or spot welding four small angles to a single plate as a web. Other manufacturers followed. But about 1923 the Massillon Bar Company (later the Macomber Steel Company) abandoned the manufacture of the strip steel joist, as that type of sheet-metal joists was known, and introduced the open-truss joist, which has since become the generally accepted type.

Standard Specification for Steel Joists.

On February 1, 1929, the Steel Joist Institute issued its "Standard Specifications for Steel Joists," which was prepared by Frank Burton after months of study. No changes have been found necessary since then, other than a few minor matters relating to the lath used for floor slab and ceiling. Criticism of these specifications has been limited. Only good can come from their promulgation. They are receiving general acceptance by building authorities. The seven members of the Institute, which includes practically all of the leading manufacturers of steel joists, have accepted the standard and are making their product conform to it. Other makers, whose trade policies preclude their membership in the Institute, are also following the specifications. The few who are not associated in this movement will, no doubt, accept the standard or be forced to do so by governmental regulation.

The term "steel joist," as defined by the standard specifications, means "any steel beam or truss shaped steel member suitable for supporting floors

and roofs when used for floor filling between the main supporting girders, beams or walls." Within this meaning a standard rolled I-beam, serving to support a floor panel between girders, would be a steel joist. This is, however, not intended; for, in a subsequent section of the specifications the spacing of joists is limited in such a way that the use of such beams would be ridiculously uneconomical. But the definition does include the light rolled sections known as "Junior Beams" made by the Jones and Laughlin Steel Corporation; and also the older forms of sheet steel joists. "Such joists may be made of rolled shapes or strips of sheet steel, round bars, angles or specially rolled bars riveted or welded together, or by expanding rolled shapes." In fact there is no restriction as to the method of manufacturing the joist, so long as the requirements of the standard specifications are complied with.

There are at present twelve makers of steel joists that would be claimed as such under the standard specifications. The majority of them offer a stock product; but some of them will furnish them only on order, fabricating them to fit according to the structural plans submitted by the designer. Due to the fact that each manufacturer of a stock product had, in the earlier days of the industry, a standard of his own, resulting in a variation of the rated capacity of joists of equal depth and span, architects and builders found it difficult to design with steel joists and to secure the greatest economy in construction. This condition was probably the greatest incentive to the organization of the Steel Joist Institute and the formulation of the standard specifications. Now the products of those manufacturers who subscribe to the standard specifications are comparable, so far as strength is concerned. The designer is not forced to find a particular make to meet his conditions of loading and limitation of depth of floor construction; and the contractor secures whatever benefits there may be in competition among manufacturers. The salesman is put on his mettle to satisfy the purchaser of the particular merits and advantages of the commodity he is offering.

Four Types of Steel Joists.

Four general types of steel joists may be recognized and conveniently designated as the sheet-steel type, the open-truss type, the expanded type, and the solid-section type, as shown in Fig. 2. The type offered by some of the manufacturers, referred to as "nailer joist," is merely a modification of any one of the four.

As already mentioned, the sheet-steel type was the first to be developed. Leaving out of consideration the limited number of such joists used in a few rare instances before 1908, the earliest form was an I-shaped joist made of two sheets pressed by machine into channel shape and riveted back to back. They were known as pressed-steel joists. Due to the method of manufacture, they were limited in length. This form was followed by the so-called strip-

steel joist, in which the two channels, which were afterward either riveted or spot welded back to back to form the I, were shaped by running strips of sheet-steel, cold, through a set of rollers. The length of the steel strips, which was indefinite, constituted the limit to the length of the joist. Both these forms of sheet-steel joists are practically obsolete, the newer forms of joist having proved to be more economical. The form of sheet-steel joist that still persists is that known as the plate-girder (P-G) type. This consists of a single sheet as a web-plate, to the long edges of which small angles are spot welded, thus forming a miniature plate-girder. (Fig. 2A.) But for this type the demand at the present time probably does not reach five per cent of the sales of steel joists. Only two manufacturers are offering this type to the building public.

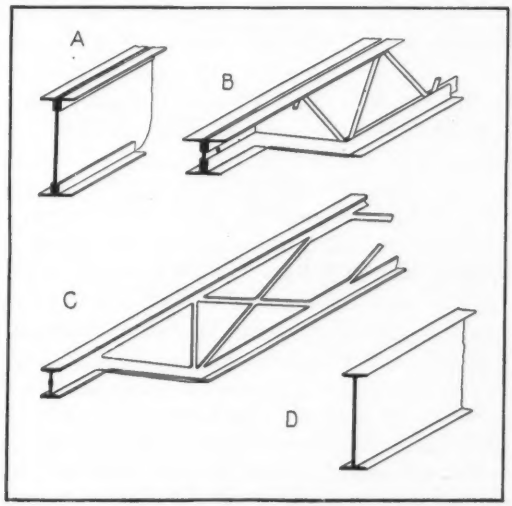


Fig. 2. Types of steel joists in general use.

Of the open-truss type (Fig. 2B), there are more varieties than there are manufacturers, as the nailer joist of any manufacturer is not quite the same as his regular joist. The differences consist chiefly in the elements that are combined to form the joist. As indicated by its name the joist has the general form of a truss. In all cases it is a suspended truss (Figs. 2B and C); in most cases the bottom chords are turned up at the ends and through a short low solid web meet with the top chord to form a seat for the joist; in some, the end diagonals of the web system are made to serve as the continuation of the bottom chord to meet the top chord at the seat. This seat, as well as the connections of web members to the chords, is electrically welded. The open-truss joist is the most popular type in use; it is generally lighter per square foot of floor area than the other types for the same loading.

The expanded type of steel joists (Fig. 2C), is also a suspended truss; but, except for the bearing plates and an extra inserted strut at the ends, there are no welded parts or connections. The web-members are integral with the chords. Two methods of manufacture are used. In one case an I-shaped steel section has the web slitted by a special machine with intermittent cuts running lengthwise of the beam, after which the section is heated and placed in the expanding machine which grips the flanges and by separating them expands the beam into a lattice truss. After straightening, the ends of the bottom chord are turned up to meet the top chord, a vertical strut is inserted and welded at each end to complete the triangular arrangement of the web members and a bearing plate is welded at the junction of top and bottom chords. In the other method of manufacture an I-shaped steel billet is rolled out and at the same time expanded, the web being slitted as in the other case, resulting in the same form of truss and finished off in the same manner at the ends.

Of the fourth type, the solid-section joist (Fig. 2D), there is only one make. It is a rolled I-beam manufactured in the same manner as standard structural I-beams. The manufacturers argue that it is a structural steel section; and in support of that claim point out that it is listed as such in the tables of properties and dimensions in the handbook of the American Institute of Steel Construction. On the other hand, the manufacturer's catalogue, in outlining the application of the joist to building construction, describes a floor assembly of the same general character as that in which other steel joists are the main supporting elements; the form of bridging is similar to that used in steel joist floor construction; lath clips, screed chairs and other accessories necessary in such construction are shown in the catalogue. Perhaps it would be fair to say that when the spacing of these joists, in any given case, exceeds that fixed by the standard steel joist specifications they should be classed as structural steel, in which case the design and details of floor assembly would be much the same as those presented in connection with ordinary structural steel construction.

The only type of steel joist in which there is variation in fabrication is the open-truss joist, the principal differences being in the shapes used for the top and bottom chords. Of eight manufacturers six use the Warren form of truss, in which the web members are all inclined, and two use the Pratt form, in which vertical web members alternate with inclined. In one of the latter cases a slight inclination, for fabricating reasons, is given to the vertical members. In all but two makes the web members consist of a continuous round bar bent to form the diagonals; one variety uses a continuous flat bar (Fig. 3F); another uses separate U-shaped pressed sheet-steel pieces. These web members are electrically welded to the top and bottom chords. In some cases pressure-welds are used and in others fusion-welds with the addition of weld

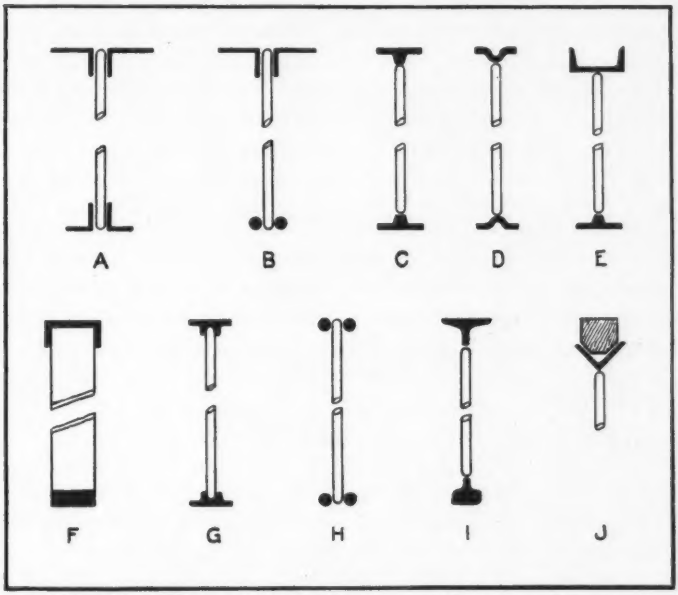


Fig 3. Cross-sections of top and bottom chords for open-truss type of joists, used by the several manufacturers.

metal, according as the fabricator claims better results. In either case the welding must be carefully done, as the connections must be capable of fully developing and transmitting stresses. Connections are expected "to withstand a stress at least three times the designed stress." It is claimed that welds that have withstood transportation and handling will not fail when the full working load is afterward applied. Great improvement has been made in recent years in the art of welding; or perhaps it should be stated in another way, that the manufacturers have developed efficient and reliable machinery for the purpose. It is said that shop inspection is thorough and that today "most of the shops have every individual weld examined and hand tested before it leaves the shop."

The sections used for top and bottom chords are not necessarily alike, and even where they have the same general shape they may differ in cross-sectional area. The top chord, being in compression, must meet different conditions than the bottom chord, which must resist tension. The requirements to be met by the top chord are: a flat top to provide a suitable surface on which to rest the flooring, whether it be of concrete or wood; a sufficient width, not only for an adequate bearing for the flooring, but also for lateral stiffness, though when the joists support a solid slab floor it may, for pur-

poses of design, be deemed to be stayed for its full length; each part for the clear distance between welds or other forms of web connections shall be designed as a column, using for that purpose the formula and allowable stresses of the American Institute of Steel Construction. The lower chord is not subject to any special restrictions other than that the tensile stresses developed shall not exceed 18,000 pounds per square inch.

Two manufacturers use two structural angles as the top chord, welding the web members to and between the vertical legs. One of them uses the same form of bottom chord (Fig. 3A); the other uses two round rods as the bottom chord (Fig. 3B). Another maker uses rolled T-sections for both chords, welding the web members to the edge of the stem (Fig. 3C). For his lighter joists he substitutes sheet-steel, pressed into a form approximating a T-shape (Fig. 3D). The rolled T-section is used in one make as a bottom chord, a rolled channel with flanges turned upward forming the top chord (Fig. 3E). The flat top is not needed in this case, as the floor construction contemplates a special metal floor-form that fits into the trough of the channel. A rolled channel with flanges turned down for the top chord and a flat bar as the bottom chord makes another combination (Fig. 3F). For the nailer joist, in this case, however, the flanges are turned upward. Still another section, used for both chords, is the twin T, that is, a T that has two stems between which the web members are welded (Fig. 3G). The earliest form, still extensively used, has two round bars for the chords, spaced far enough apart to take the web members between them (Fig. 3H). A rolled section having the shape of a railroad rail, cut apart along the web, furnishes the T-shaped base as the top chord, and the head with part of the stem turned upward as the bottom chord of a further variety of joist (Fig. 3I). For nailer joists, besides the channel with flanges turned upward, equal-leg angles, so set that they form a triangular trough, with the web members welded to the corner of the angle, are used as top chords (Fig. 3J).

There are other details of design that require study to produce an efficient, economical joist. The consulting engineer to the Steel Joist Institute refers to the industry as highly specialized, "requiring thoroughly trained technical service and a great deal of special machinery and much skilled labor." A matter of importance is the proper proportioning of the seat-end, "to properly take care of the stresses developed in the top chords due to the cantilever action of the joist end" (Figs. 2B and C). Only in comparatively few instances are steel joists designed and fabricated, as structural steel, to fit a particular plan. As a stock product these joists cannot well be made to meet every possible variation of span. The majority of the manufacturers have so designed them that a variation of six inches in span is possible; one manufacturer provides for a variation of one foot. For economical shopwork the panel lengths are made uniform and differences in length are made in the

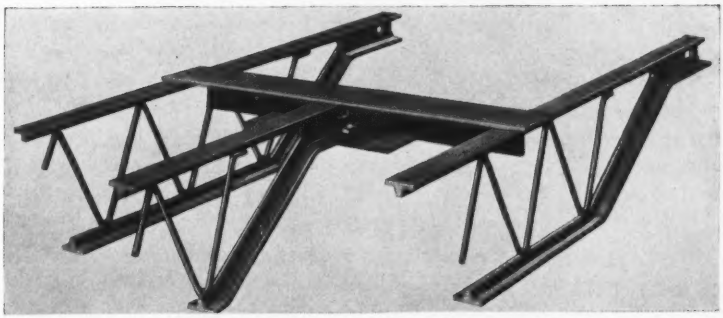


Fig. 4. A type of header for small floor openings.

end panels, necessitating, in some cases, special treatment of the end web members.

Open-truss and expanded joists are available in 8-, 10-, 12-, 14-, and 16-inch depths, this being the overall dimension. The effective depth, of course, varies with the type and cross-sectional area of the chord members. For sheet-steel (P-G) joists the depths vary by single inches from six to fourteen. The solid-section joists also vary in depth by single inches from six to twelve. Since the standard specifications limit, except for solid-web joists, the span to twenty-four times the depth of joist, the maximum lengths in feet are fixed at twice the depth of the joist in inches. It is also provided that the joist shall be stiff enough to keep the deflection under the full rated load to one three hundred and sixtieth of the span. To make sure that vibration as well as excessive deflection is avoided, Mr. Burton suggests that the span should not exceed twenty-two times the depth of joist.

Efficiency Dependent on Workmanship.

As the efficiency of the steel joist is dependent on thorough workmanship in the shop, so the safety of steel joist construction is dependent on proper installation in the field. When joists rest on masonry or reinforced concrete the bearing should be at least four inches; when resting on steel, at least two and one-half inches. For the purpose of anchoring, joists generally have small openings in the seat-end through which anchors, supplied by the makers, are passed. The anchors used when the joists rest on masonry or reinforced concrete are, with some variation, like those used with structural steel; they should be made of $\frac{1}{4}$-inch round bars or their equivalent; every third joist should be anchored. When resting on steel beams every joist should be anchored or otherwise secured. Various forms of anchors are sent with the joists, all seeking to hook the joist over the flange of the beam on which they rest. If they rest on shelf angles some form of bolting is used. Advocates of steel joist construction generally hold that rigid connections should be

avoided; though the standard specifications require that in buildings the height of which exceeds twice the least dimension at the base "each joist shall be welded to the steel work with two welds at each end, each one inch long" or secured by a half-inch bolt or rivet. Welding, while adding to the cost of installation, does provide rigidity during construction and will possibly prevent accident due to knocking joists off their supports before the bridging has been placed.

Framing Around Floor Openings.

Steel joists should not be used for framing around floor openings, unless the openings are comparatively small, or perhaps when the floor loads are very light. Such framing should be done with standard rolled shapes. For framing around a flue or a small dumb-waiter shaft, some of the manufacturers supply special headers with suitable hangers (Figs. 4 and 5).

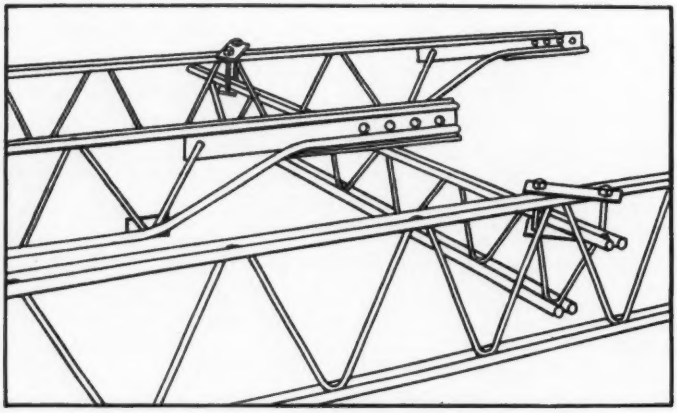


Fig. 5. Another type of header for small floor openings.

Floor Deck Construction.

The contention that the floor-deck supported by them, being of a different material and governed by different principles of design, is not a part of the steel joist construction, is hardly tenable. As already indicated, the standard specifications recognize the floor slab as furnishing the necessary lateral stiffness to the top chord, making it unnecessary to consider the radius of gyration around the vertical axis in the design of that member. The materials that have been in use for the floor deck are wood, gypsum and concrete. On the type of decking depends, in a measure, the spacing of the joists. For flat wood decks of single $\frac{7}{8}$-inch thickness, securely fastened to nailer joists, the spacing should not exceed twenty inches for floors, or thirty inches for roofs.

For other materials twenty-four inches for floors and thirty inches for roofs are set as the limits. When the joists support roofs of wood or sheet-metal only, the spacing may be increased to seven feet. There is, of course, the further limitation, in every case, that the spacing shall not exceed that for which the decking is safe for its load.

When gypsum is used as the decking, it is sent to the job in the form of precast slabs, the length of which fixes the spacing of the joists. Such slabs, unless rabbeted at the bearing edges to extend below the top of the top chord, must be otherwise secured to afford the necessary lateral support. Poured slabs of gypsum, however, are in no way precluded. Whether precast or poured they must be at least two inches thick.

Concrete Floor Slabs.

The poured concrete floor slab is the form most generally advocated for steel joist construction (Fig. 1). Care should be exercised in its design, remembering that it is reinforced concrete. It must be made thick enough, but not less than two inches in any case, and the actual moments developed must be resisted by reinforcement properly placed. Steel joists have been at times unjustly blamed for cracks that occurred in the concrete over them, when the fault was really chargeable to the slab design. The slab must be securely attached to each joist so that it will serve its purpose of lateral support for the top chord. This can be and generally is effectively accomplished through the medium of the reinforcement, which serves also as the form for the concrete, since only in rare instances is removable form work used.

The most commonly used material, as combined form and reinforcement, is ribbed metal lath. The standard specifications call for a lath weighing not less than four pounds per yard, with $\frac{3}{8}$-inch ribs, or other incombustible material of equivalent strength and stiffness. Several forms of clips, generally of wire of about No. 12 gage, to fasten the lath to the upper chord at intervals of eight to twelve inches, are furnished by the steel joist makers. When the top chord consists of two parallel bars or shapes with a space between, soft wooden wedges driven through the lath into this space may be used instead of the clips. Another material that has come into use is a composite fabric of rectangular wire mesh with a damp-proofed paper backing. The No. 12 gage wires are slightly raised above the backing by crimps in the mesh to insure embedment of the wires in the concrete. The backing, serving as a form, and being solid and waterproof, permits of more freedom in the concrete mixture, as there is no seeping of cement-bearing water through the forms; that is, an adequate amount of water can be used without fear of disturbing the ratio of the ingredients of the concrete. An advocate of this type of reinforcement holds that the ribbed metal lath does not serve effectively unless back-plastered. In the application of this material to floor construction, it is fastened at one end of the floor space, rolled out—it is shipped in rolls of 125-foot

lengths—across the joists stretched taut—stretching tools are sent with each shipment—and fastened with clips or wedges as metal lath would be. Objection has been made that in the process of stretching there is danger of distorting the joists laterally, or disturbing them on their seats, and thus weakening the floor construction. This danger does exist when wire bridging is used; but if the bridging and anchoring contemplated by the standard specifications is used there should be no trouble.

Reference has already been made to the form of construction in which ribbed, solid plate decking, interlocking with the top chords of the joists, is used. The decking consists of No. 20 gage sheet steel, and is made in lengths to suit 12-, 17-, 19-, 21-, 23-, or 25-inch spacing of joists. The concrete slab above it, in this case, is practically only a floor surface, which, it is claimed, is "as near crackless" as can be made. This form is rapidly erected, assures

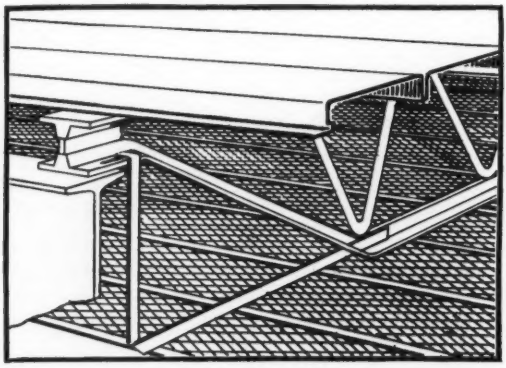


Fig. 6. Channel plate floor deck.

rigidity, retains the water of the slab concrete, and offers a working floor for other mechanics as soon as it is put in place. The same advantages obtain in a newer development of a so-called channel-plate floor (Fig. 6). In form the units are substantially the same as the older pressed sheet steel channels. They are laid side by side, that is, the flanges touching, across the tops of the joists, bolted or welded to them, presenting a smooth flat metal surface, on which it is possible to place directly any floor finish that is applicable to the top of a concrete slab. Experience with this construction is, however, still rather limited.

When concrete floors are to be finished with a wooden surface, wooden screeds or sleepers must be embedded in the slab to which the flooring is nailed. These should be made to run at right angles to the joists to avoid breaking the continuity of the concrete over the joist, though some makers assume that they may run with and directly over the joist. In the latter case

they should be kept at least an inch above the top of the joists; in fact, this elevation is desirable in any case. For this purpose the manufacturers make some form of "screed chair" to be fastened to the top chord of the joist.

Ceiling Construction.

Except when fire-resistance is contemplated, ceilings are not a necessary part of steel joist floor construction. However, when provided they should be rigidly supported and amply secured to the joists. Ordinarily they are of metal lath and plaster. The lath may be clipped directly to the lower chords; or, preferably, it may be supported through the medium of metal furring, having a small space between the metal lath and plaster, and the joist. Precast gypsum ceiling blocks are also quite extensively used. These blocks are reinforced, interlock with one another and are suspended by protected metal hangers.

In joists in which the lower chord turns upward at the ends, leaving a gap between the joist and its support, "ceiling brackets" to support the ceiling construction must be attached to the joists. These are supplied by the manufacturers and generally consist of round rods or flat bars, so shaped as to hang from the top chord close to the support and to form an extension of the lower chord across the gap, being secured to the bottom chord at the lower end of the inclined section (Fig. 6).

Bridging.

An element of first importance in steel joist floor construction is proper bridging. Probably many of the failures that have occurred were due to a neglect of this feature. Builders need to have the importance of this point impressed on them. Their frequent neglect in the past to bridge the joists properly was probably due to ignorance of or indifference to the principles involved. It is of no avail for the manufacturers to contend that the duty to see that proper bridging is installed devolves on the building authorities. If there is trouble due to inadequate bridging, the public puts the blame on the joist. Furthermore, the nature of the joist demands attention to this point, for concentration of load over one joist will overload that joist, and, due to deflection, will probably throw undue stress into the slab above it. The subject has given the advocates of this construction considerable concern from the earliest development of the industry.

The object of bridging is multifold. It must "support the top chord against lateral movement during the construction period." It must hold the joist in a vertical plane. It must adequately distribute loads throughout the floor construction, for this type of construction contemplates uniform distribution of the load. It must help to prevent excessive deflection in the joist. It must assist in keeping vibration at a minimum. It is unsafe to use steel joists as a working platform until the bridging is in place. The standard specifica-

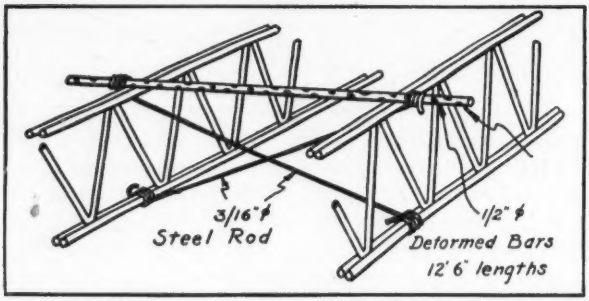


Fig. 7. Wire bridging according to standard specifications of the Steel Joist Institute.

tions provide that the bridging shall be "capable of transferring five hundred pounds from each joist to the adjoining joists." A further requirement fixes the minimum spacing of bridging at one row, approximately at the center, for spans up to 14 feet; two rows, evenly spaced, for spans of 14 to 21 feet; and three rows, evenly spaced, for spans of 21 to 32 feet, the maximum permitted.

The simplest form of bridging that has been used, in fact was universally used before the subject was seriously studied by the consulting engineer to the Institute, and is still used because of its low cost, is a continuous wire running from the top chord of one joist to the bottom chord of the other, crossing another that passes from the bottom chord of the first to the top chord of the latter, both being wrapped around the joists or their chords at each end, the same procedure being followed throughout the entire floor space (Fig. 1). Where the wires cross they are twisted over one another to make them taut. This type of No. 14 gage galvanized wire is still recommended by one manufacturer, but with the proviso that the lines of bridging shall not be spaced more than four feet apart. This type of bridging falls far short of the minimum acceptable under the specifications. It is evident that unless the greatest care is exercised, distortion of the joist is sure to result from uneven force exerted in twisting, even though temporary spacers are placed between the top chords as recommended by the manufacturer.

Where this form of bridging is desired, the standard specifications require for the diagonals at least a 3/16-inch round rod or its equivalent, supplemented by a continuous strut—not less than a $\frac{1}{2}$-inch round rod—between the top chords (Fig. 7). Even this seems hardly adequate to accomplish fully the purpose of bridging. Most of the manufacturers, therefore, have developed various forms to suit their particular product as a preferable alternative to the minimum of the specifications. One form consists of a Warren truss made of $\frac{3}{8}$- and 5/16-inch round rods that pass through the web panels of the joists and is either clamped or wired to the top chord and, at the lower end, to a diagonal (Fig. 8). Another form consists of horizontal channels, either

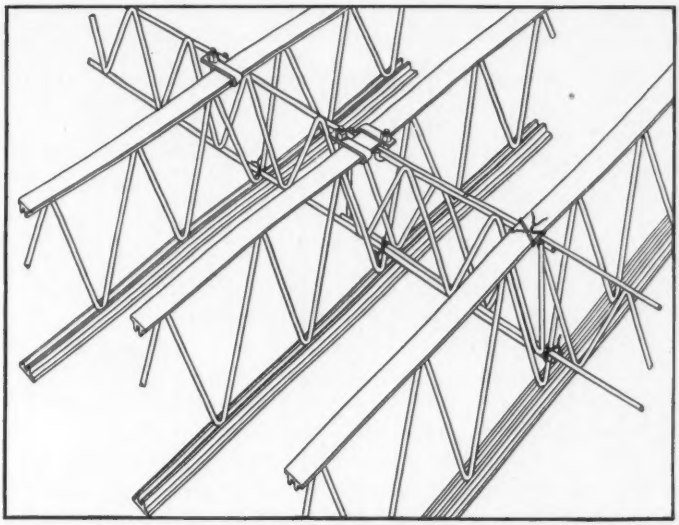


Fig. 8. Truss bridging showing two methods of fastening to top chord.

rolled shapes or pressed sheet-steel, in one case, bolted or clamped to the top chord (Fig. 9), or, in another case, swedged to the side of an extra vertical web member of each joist. One manufacturer uses a ⅜-inch square steel bar, clamped to the upper chord. Several makers supply channels, cut to lengths to suit the spacing of joists, so fabricated that they are readily wedged in between the top chord of one joist and the bottom chord of the next, and secured to the chords, forming, when completed, a rigid series of cross bridging across the floor (Fig. 10). In one system of floor construction, which is more or less special in all its details, provision is made for extending the concrete floor slab at the center of the joist downward to form a reinforced concrete beam. This is supplemented on long spans by wire cross-bridging at intermediate points. The floor construction should be anchored at the ends of each line of bridging (Fig. 9).

Strength of Steel Joists.

The standard specifications contemplate that steel joists shall be so designed and fabricated that their strength, that is, their safe load-bearing capacity, can be definitely calculated. Those having solid webs are to be figured as beams, with maximum fiber stresses in compression and tension of 18,000 pounds per square inch. Those with open webs are to be designed as trusses. Standardization of the latter type has been so far accomplished that the manufacturers have so modified the various elements of their products that the safe loads are at least equal to, if not somewhat in excess of, those

Properties and Allowable Total Loads in Pounds per Linear Foot of Open Web Steel Joists

STEEL JOIST INSTITUTE STANDARD

American Institute of Steel Construction Stresses. Adopted by Steel Joist Institute Aug. 20, 1929. Effective Jan. 1, 1930

Steel Joist Institute Designation	SJ81	SJ82	SJ102	SJ103	SJ104	SJ123	SJ124	SJ125	SJ126	SJ145	SJ146	SJ147	SJ166	SJ167	Steel Joist Institute Designation
Depth In Inches	8	8	10	10	10	12	12	12	12	14	14	14	16	16	Depth in Inches
Resisting Moment In Inch Pounds	29,500	52,500	63,000	82,000	100,000	92,000	115,000	142,000	175,000	156,000	205,000	246,000	232,000	281,000	Resisting Moment In Inch Pounds
Maximum End Reaction In Pounds	1600	1900	1900	1950	2200	2200	2300	2500	2700	2900	3100	3400	3200	3600	Maximum End Reaction In Pounds
Span 4 Feet	800														Span 4 Feet.
5	640														5
6	530														6
7	402														7
8	308														8
9	243														9
10	197	350													10
11	162	289													11
12	137	243	292												12
13	116	207	248												13
14	100	178	214												14
15	87	155	187	243		272									15
16	77	137	164	213	260	240									16
17			145	189	230	212									17
18			130	169	205	189	236								18
19			116	151	184	170	212			288					19
20			105	137	167	153	192	237		260					20
21						139	174	215		236					21
22						127	158	196	241	215					22
23						116	145	179	221	197	258				23
24						106	133	164	202	180	237				24
25										166	218	262	247		25
26										154	202	243	229		26
27										143	187	225	212	257	27
28										133	174	209	197	239	28
29													184	223	29
30													172	208	30
31													161	195	31
32													151	183	32

*Note. These Joists are not produced by all Manufacturers.

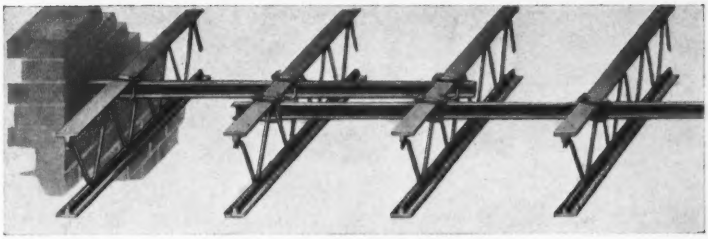


Fig. 9. Channel bridging.

given in the standard table of allowable loads. (See table.) The joists listed in the table are stock sizes; special designs to meet special conditions are not precluded. The reliability of the calculated loads has been checked by numerous tests. It is claimed that in no other industry have more actual physical tests been made in the way of research by the different makers. Tests have also been made as official demonstrations, the results of which are available. An analysis of ten of these latter load tests, made on two types of truss joists and two makes of expanded joists, indicates that factors of safety over the rated safe loads range from 2.10 to 3.24, with an average of a little more than two and one-half. In these tests, two, three or four joists were set up on appropriate supports, with varying spans up to 20 feet, carrying a concrete floor slab as it would be constructed in a building. The joists under test were 8, 10, 12 and 14 inches deep, and were, in all cases, bridged at the one-third points, or at the center and one-quarter points, in two cases with rigid bridging and in two with wire bridging. The load was applied uniformly over the floor surface, except in two cases, in which it was applied at the one-third points.

In an earlier series of five load tests, made on the truss type of joist without the slab, in which the load was applied at the one-third points, the margin of safety developed was not quite so large. The joists were bridged with wire at the one-third points and in addition the top chords were braced laterally at the same points. The joists were 8, 10, 12, 14 and 16 inches in depth. Failure occurred when the loads reached about one and three-quarters to two times the safe load as determined by the present method of the Steel Joist Institute. The factor of safety over their current catalogue-rated load was hardly more than one and one-half. Since these tests were made, however, there has been considerable improvement in manufacture.

That the slab as part of the floor construction, when properly attached to the top chords, does contribute to the supporting ability of the joist can hardly be doubted. Not only do the tests just referred to show this, but another official test made on a single joist of the truss type, with a uniformly distributed load, developed a factor of safety of ten per cent less than that made on the same make of joist tested with the slabs. Quite properly a note

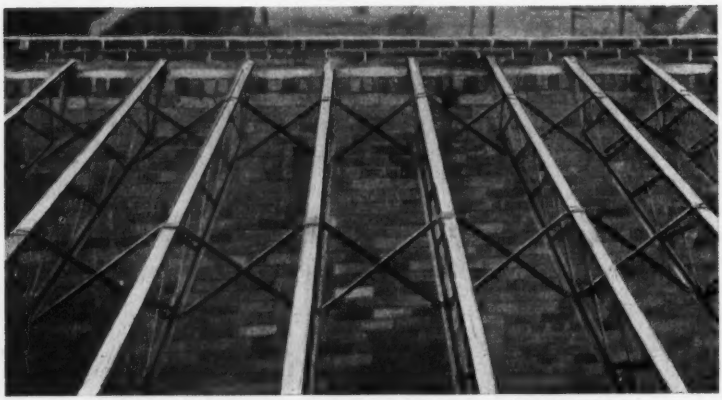


Fig. 10. Rigid cross bridging of pressed sheet-steel channels.

in the standard specifications holds that in making load tests, steel joists should be "used, bridged according to the method used in the field and provided with a top slab or deck as nearly as possible like that to be used in actual construction." But this also emphasizes the fact that the slab is an essential part of steel joist construction. The standard specifications require that "the maximum uniform load at failure shall not be less than the dead load plus two and one-quarter times the designed live load."

Whether a factor of safety of two and one-quarter is adequate or not is a matter of judgment. It is claimed by the advocates of steel joist construction that in structural steel the margin, based on a fiber stress of 18,000 pounds per square inch, is no greater; in support of which reference is made to sixty-three tests of standard rolled I-beams and girders, varying in depth from three inches to thirty inches, developing an average factor of safety of 2.18, varying from a minimum of 1.72 to a maximum of 2.99. The comparison, without consideration of the conditions under which the tests were made, is hardly a fair one. The tests of steel joists, in all but one case, were made on groups of two or more joists, and in the one exception the factor of safety was only 1.91; whereas the tests of standard rolled shapes were all on single beams. In the majority of the tests of steel joists, the loads were uniformly distributed; whereas in all of the other tests the loads were concentrated either at the center or else at the one-third or one-quarter points. In the tests on standard I-beams, the loads were applied directly to the shapes, without the intervention of a slab. When structural steel is encased in concrete, as it generally is in building construction, the stresses in the steel are reduced by about thirty-six per cent under dead and full live load.

Due to the disposition of the metal, steel joists of the truss type are more rigid in proportion to their weight than any type of joist or beam with solid

webs. The standard specifications, applicable to all types, however, seek to keep the deflections within the limit generally accepted to prevent the cracking of plastered ceilings, that is, within one-three hundred and sixtieth of the span. So far as shown by readings taken in connection with load tests on the truss types, this deflection is not reached until the rated safe load has been greatly exceeded.

One commentator on steel joists refers to a residual deformation in the truss type "which must be removed before the joist is efficient in sustaining a load." He attributes it to "failure to remove all free bends" in fabrication. So far as observable the load tests have not revealed any effect due to such condition. In one test the value of rigid bridging was evident. The test panel was originally supported by six joists, only four of which, however, were being loaded. After the loading had proceeded to approximately ninety per cent of the rated safe load the two marginal joists were cut in two, throwing the load entirely on the four interior joists. This caused an increase in the deflection of load-carrying joists of fully fifty per cent.

Corrosion.

The extent to which corrosion will affect steel joist construction is a pertinent question. In the earlier type of joist made of comparatively thin sheet-metal this matter was of serious import. Moisture may find its way from the mopping up of floors to the joists through accidental holes in the floor slab, from leaking pipes or from condensation on cold water pipes that are located in the hollow spaces of the floor construction. Corrosion from such cases has occurred. The permanence of the joists and the metal lath of the floor and ceiling construction in warm, humid localities along the seacoast has repeatedly been questioned. One case is reported in which joists of the sheet-metal type were corroded to the extent of fully fifty per cent. In buildings in which moisture is a usual concomitant of the occupancy, such as laundries, creameries, or cheese factories, it would probably be unwise to use structural elements of light steel. The Wisconsin State Building Code provides:

> Steel joists shall not be used in first floor panels having less than five feet of well-ventilated air space below, nor in floor panels over damp basements.
>
> Piping installed in the enclosed space between the top slab and the protection for the under side of steel joists shall be limited to water supply and waste pipes and electric conduit; all such pipes conveying liquids shall be insulated to prevent the condensation of moisture on the pipes. Pipes conveying steam, gases, chemicals and similar active fluids shall not be installed in enclosed spaces with steel joists.

On the other hand, there are many structures standing today, erected within the past decade or longer, in which suitable provision has been made to avoid the penetration of moisture to the joists, to insulate cold pipes properly, and to guard against free air circulation, to satisfy the building public of the reasonable permanence of steel joists as marketed at this time. The late

William C. Robinson, while emphasizing the importance of durability, thought that the conditions that would have a deteriorating effect "would be well recognized by the person building the building as well as the company furnishing the materials," so that so far as the average building is concerned there is not much to fear. The case is cited of the building erected in New York City in 1855, in which joists of sheet iron, galvanized, when removed in 1916, were found to be in "perfect condition." As one safeguard the standard specifications require that "all joists shall receive one coat of good paint by dipping or spraying before leaving the shop." One manufacturer uses copper bearing steel in his product. The material generally used is steel, conforming to the A.S.T.M. standard specifications for structural steel for buildings.

Fire Resistance.

The industry regards steel joist construction as fully entitled to recognition as fire-resistive when constructed as prescribed in its standard specifications. Under the insurance rating schedule prevailing throughout the Middle Western states the construction is recognized as "fireproof" when "the steel supporting members are properly fireproofed." Under the 1931 revised code of the National Board of Fire Underwriters it would be classed according to the ultimate fire-resistance developed under the standard fire test (A.S.A. Tentative American Standard—1926), as "fireproof" if a three-hour performance and as "semi-fireproof" if a two-hour performance resulted, relying on the building official to decide in each case. The Building Code Committee of the U. S. Department of Commerce classifies it as Type 1, Fully Protected (requiring a 2½-hour rating or better), when the floor slab is of concrete or gypsum two inches or more in thickness and the ceiling is Portland cement mortar or gypsum plaster, at least one and one-half inches thick, on metal lath, furred out to furnish a one-inch air space between the bottom chord of the joists and the ceiling; and as Type 2, Protected (requiring a 1½-hour rating or better), when the floor slab is of concrete or gypsum two inches or more in thickness and the ceiling is gypsum or Portland cement mortar, at least seven-eighths of an inch thick, on expanded metal or wire lath.

The standard specifications of the Steel Joist Institute provide as follows:

Steel joists with or without a wood nailing strip above, when protected with a ceiling of metal lath and plaster three-quarters inch thick, may be used wherever a one-hour fire resistance is required. A wood top floor may be used in such cases.

Steel joists protected with a ceiling of metal lath and gypsum or Portland cement plaster at least three-quarters inch thick may be used wherever a two-hour fire resistance is required. Joists for this purpose shall not have any wood nailing strip attached thereto and shall be covered with a top slab of concrete at least two inches thick cast upon metal lath or other incombustible material. Wood nailing strips may be embedded in this concrete slab if protected on the bottom with not less than one inch of concrete.

Steel joists protected with a ceiling of metal lath and gypsum or Portland cement plaster at least one inch thick may be used wherever a three-hour fire resistance is re-

quired. Joists for this purpose shall not have any wood attached and shall be covered on top by at least two and one-half inches of solid concrete. No wood nailing strips shall be used in such top slab.

Steel joists protected on the bottom with a poured or precast reinforced gypsum slab not less than two inches thick and otherwise in accordance with [the requirements for three-hour resistance] may be used wherever a four-hour fire resistance is required.

Fire Tests.

The bases for these several standpoints are largely the fire tests that have been made on steel joist construction or somewhat similar floors. As yet there has been no recognized public or official test on steel joist floor construction made in accordance with the standard fire test specifications. Two private tests were conducted in which the prescribed procedure of the standard test was substantially followed, but both were made more than eighteen months before the approval (November 8, 1926) of the test specification as "Tentative American Standard."

(1). Although regarded as private, the second of these tests was witnessed, on invitation, by a number of building officials, and the results were discussed at a public meeting on the day following the test, so that fairly complete information is available. The construction under test consisted of a series of 8-inch strip-steel joists (sheet-metal type) spaced 15¾ inches on centers, stiffened by wire bridging, and with a clear span of sixteen feet. The floor deck was a two-inch concrete slab, reinforced with herringbone lath resting on top of the joists. The ceiling was of metal lath and plaster, having an average thickness of 1-5/16 inches under the joists, directly attached thereto. About ⅜-inch clearance was allowed at each end of the joists for expansion. During the test the floor carried a superimposed load of ninety-two pounds per square foot, uniformly distributed. The dead load was about 41 pounds. The loading was such as to produce a maximum fiber stress of 16,000 pounds. The furnace temperatures approximated quite closely the standard time temperature curve. The fire was shut off at the expiration of two hours and two and one-half minutes, when the transmitted temperature to the top surface of the floor was 250 degrees Fahr. At one point the temperature on the top surface had reached 300 degrees and continued to rise for an hour after the fire was discontinued till it reached 400 degrees. The temperatures (Fahrenheit) developed at the end of the fire test were: in the furnace 1840 deg. average; on the lower flanges of the joists 922 deg. average, 950 deg. maximum; on the upper flanges 559 deg. average, 600 deg. maximum; in the joist space 747 deg. average, 835 deg. maximum; and on the top surface 256 deg. average. The construction generally remained in good condition throughout the test, except for an unevenness of the ceiling, which began to develop after the first half hour, peeling of the plaster, without, however, at any time exposing metal lath, checking of the plastering and one

serious crack which started to develop about fifteen minutes after the fire started and continued to develop until, at the end of the test, it was about two and one-half feet long and extended through the ceiling to the hollow spaces. It was over this crack that the greatest heat transmission occurred. No water was applied at any time.

(2). In the other of these two private tests, a similar construction was under examination. In this case the end point was declared at two hours and forty-six minutes, when three pyrometers on the top surface indicated a temperature of 300 deg. Fahr. The average temperatures (Fahrenheit) at the extinguishment of the fire were: in the furnace 1920 deg.; on the lower flanges 1108 deg.; on the upper flanges 860 deg.; in the joist space 844 deg.; and on the top surface 276 deg. No allowance had been made for expansion of the joists and considerable distortion occurred. The superimposed load was 100 pounds per square foot. There was no structural failure.

(3). In 1914, September 1, a fire test was made at the Columbia University Testing Station, for the building authorities of New York City. The floor construction under test consisted of 8-inch strip steel joists (sheet-steel type) spaced 13⅜ inches on centers, supported on shelf angles riveted to the webs of 12-inch, 31½ lb. I-beams, carrying a deck slab, two inches thick, of 1:2½:5 cinder concrete on expanded metal lath, and protected by a 1-inch, three-coat plaster ceiling on expanded metal lath. The joists had a span of fourteen feet. The supporting I-beams had a clear span between the walls of the test chamber; and their lower flanges were protected by metal lath and plaster similar to the ceiling construction, with an air space between the steel and the protection. Three lines of ribbon bridging, 1 inch, 20 gage galvanized steel, had been provided, one at the center of the joists, the others two feet from the supporting I-beams. During the test the floor carried a superimposed load of 150 pounds per square foot. The furnace temperatures were approximately those specified by the New York test specification, namely, a rise to 1700 deg. F. at the end of the first half hour, maintained at that for the balance of the test. The temperatures in the inter-joist space rose to 584 deg. at 30 minutes; 945 deg. at 60 minutes; 1110 deg. at 90 minutes; 1225 deg. at 102 minutes, at which time the floor collapsed. During the period of curing two cracks developed in the ceiling, which, with further cracks that started during the test, "doubtless had some effect upon transfer of heat to the air space between slabs."

(4). A second test on the same form of floor construction was made, April 14, 1915, at the Columbia University Testing Station. In this case 7-inch joists, sheet-steel type, spaced 15-6/10 inches on centers were used. Their span, however, was reduced to twelve feet. The ceiling consisted of 1:2½ Portland cement mortar on expanded metal lath, held off the soffits of the joists by 1-inch U furring placed 13½ inches on centers. This ceiling, of a wet

consistency, almost a grout, was poured in place on wood centering hung about one inch below the lath, and when finished had an average thickness of one and one-half inches. The lower flanges of the supporting I-beams were solidly encased, two inches thick below and about one and one-half inches outside the edges. In other respects the construction was the same as in the earlier test. The loading again was 150 pounds per square foot. This construction successfully passed the 4-hour fire test. The deflection of the joists was slightly less than seven-eighths of an inch. The average furnace temperature was 1677 deg. F. The average inter-joist temperatures were: 219 deg. at 30 minutes; 365 deg. at 60 minutes; 740 deg. at 120 minutes; 955 deg. at 180 minutes; 1046 deg. at 240 minutes. The hose stream, 60 lb. nozzle pressure, applied at end of fire test washed away the plastering to a depth of $\frac{3}{8}$ to $\frac{1}{2}$ inch and exposed only a small amount of metal lath. The superimposed load was increased to 600 pounds per square foot after the construction had cooled off, under which the slab deflection increased to one and three-quarter inches. After removal of the load and the top slab it was found that there had been a "very slight lateral distortion of the joists." The ceiling between joists was "strong enough to walk on."

(5). The only fire test on the truss type of joists of which there is any report is one made by the Pittsburgh Testing Laboratory in May, 1926, for the manufacturer of the joist. The procedure followed was neither that of the A.S.A. Tentative American Standard nor the earlier A.S.T.M. standard. The floor under test had an area of sixty-three square feet, which is about one-third of that required under the present standard. The span of the joists was 10 ft. 6 in., that is, 1 ft. 6 in. less than required by the present standard and 3 ft. 6 in. less than the earlier standard. The furnace temperature rose from that of the air to 1800 deg. Fahr. in the first three-quarter hour and was maintained at that heat (average) for three hours and forty minutes. The floor under test consisted of five 8-inch open-truss joists, supporting a 2-inch concrete slab on metal lath, reinforced with $\frac{1}{4}$-inch rods in both directions, and with $\frac{1}{2}$-inch surface finish, and protected by a ceiling of $\frac{3}{4}$-inch cement plaster on metal lath secured to the bottom chords through the medium of 7/16-inch pencil channels spaced twelve inches on centers. During the test this floor carried a load of about 150 pounds per square foot. At the end of the test the temperature in the inter-joist space had risen to an average of 870 deg. and "the temperature at the top of the concrete slab . . . . did not exceed 160-170 degrees." "With the exception of slight checking at the sides, the ceiling remained in a practically perfect condition under the fire test." The joists were distorted laterally, though, under subsequent loading, they had apparently retained their strength.

(6). Concerning two unofficial four-hour tests on strip-steel joist construction, in 1911 and 1913, no information is available, except that in the

later test "a great part of the ceiling, which was wet and green, fell when the fire first started."

(7). A one-hour test made by the Prussian State Department of Testing Materials in 1929 might also be mentioned. The test panel, approximately square, had an area of 170 square feet. It consisted of six 7-inch sheet-metal joists spaced twenty-three inches on centers, with a clear span of thirteen feet. The floor deck was a concrete slab, two and one-half inches thick on ribbed metal lath. The ceiling was a gypsum-lime plaster, one inch thick, with a $\frac{1}{8}$-inch finish. The floor carried a load of about 31 pounds per square foot. The furnace temperatures had reached more than 1800 deg. Fahr. in the first half-hour, and had risen to nearly 2100 deg. when the fire was discontinued. The temperature on top of the floor was 115 deg. when the fire was extinguished and rose to 162 deg. in the next hour and forty minutes. The temperature between joists was not recorded, but in the air space in the rear wall of the combustion chamber, constructed as the ceiling, the temperature recorded at extinguishment of the fire was 890 deg. Fahr. "No apparent injury had been inflicted on the joists or the expanded metal. The concrete floor slab was perfectly preserved."

(8). Incidental to a test made in 1928 on masonry walls, a panel about 160 square feet in area, of "steel joists [presumably sheet-metal type] and woven wire sheeting, plastered underneath with two coats of plaster and covered on top with a two-inch layer of concrete, forming the roof of the test structure, was subjected to a two-hour wood fire. The furnace temperatures as reported, 1940 deg. Fahr. within five minutes of the lighting of the wood and maintained at an average of about 2000 deg., may be questioned, as they were determined only by an optical pyrometer. No other temperatures were noted. "The roof had been loaded with a layer of concrete blocks, and the heat had weakened the steel joists so that they sagged down under this load in the middle of the roof."

In this connection reference may be made to two tests made for the building authorities of New York City, at the Columbia University Testing Station. Both tests were made to show the fire-resistive qualities of their respective forms of gypsum ceiling and floor slabs. The furnace temperatures were those of the New York specifications. In both cases the four-hour fire test was completed; the hose stream was applied, resulting in the washing away of practically all of the ceiling; the 150-lb. load during the test was increased to a 600-lb. load without undue distress in the construction. While the constructions under test were of the same general form as the usual steel joist floors, the carrying elements were standard structural channels. This represents a weight of steel per square foot of floor nearly double that of the heaviest steel joist of the same depth and spacing, and from three to four times that of the lightest, and hence a greater amount of steel to absorb the

heat, a fact which must be kept in mind when these tests are used in comparison with fire tests on steel joist floors.

(9). In the test made May 4, 1926, 9-inch 13.4-lb. channels were used, spaced 30 inches with a span of 14 feet. The floor slab was poured gypsum 2½ inches thick on ½-inch gypsum wall boards as permanent centering, reinforced with No. 10 galvanized wire, 4- by 8-inch mesh. The ceiling was poured gypsum 2¼ inches thick, reinforced with No. 12 galvanized wire, 2- by 4-inch mesh, finished off with ¾-inch gypsum plaster, a total thickness of three inches. The temperatures, degrees Fahrenheit, developed were:

Expired time—minutes	60	120	180	240
Lower flange of channels.....	135	183	196	201
Top of floor.....	55	71	103	125

(10). In the test made December 6, 1922, 10-inch 15.3-lb. channels were used, spaced 24 inches, with a span of 18 feet. The floor slab consisted of precast gypsum blocks two inches thick, reinforced with 3/16-inch steel rods, six inches on centers, projecting 2½ inches at each end for twisting to the reinforcement of the adjoining block, with a cinder concrete fill three inches thick over the blocks. The ceiling consisted of precast gypsum blocks two inches thick, reinforced with 3/16-inch steel rods, twelve inches on centers, supported from the top flange of the channels by 3/16-inch rods, finished off with ¾-inch plaster on under side. In this case temperatures of the interior spaces or on the top surface were not taken.

These several fire tests, although none that might be regarded as official under the standard fire test, furnish useful information for conclusions as to the fire-resistive qualities of steel joist construction. Where failure occurred it may be generally attributed to defective workmanship—as in the case of the serious crack that developed in the first test described herein—a contingency, in the type of ceiling construction used, that is met frequently. The more important facts, however, on which apparently the standard specifications mainly rely, are the temperatures developed in and above the construction. The standard fire test prescribes as one of the conditions of acceptance for a given time rating, that the temperature on the unexposed surface shall not exceed 250 deg. Fahr. above the initial temperature at that point. The testimony in the preceding tests varies considerably on this point. Disregarding momentarily differences in construction, the reports show average temperatures:

1. At 2 hr. 2½ min. 256 deg. (maximum 300)
2. At 2 hr. 46 min. 276 deg.
5. At 4 hr. 28 min. 160-170 deg.
7. At 1 hr. 5 min. 115 deg.
9. At 4 hr. 125 deg.

The reports on Nos. 1 and 7 indicate that the transmitted temperatures continue to rise for a considerable time after discontinuance of the fire. The

earlier end point of No. 1 as compared with No. 2—construction in the two cases being similar—was probably due to the ceiling crack that developed. The low figures in the case of No. 5 are undoubtedly due to the fact that "during the test the corners of the concrete slab on top of the joists were warped to some extent," permitting heat to escape. This warping no doubt also affected the temperatures of the inter-joist spaces which at two points had reached 1000 deg. At 1000 deg. the elastic limit of steel has fallen dangerously near the working stresses used in designing steel joists. When temperatures rise to 300 deg. Fahr. they are dangerously near the ignition points of light flammable materials. The various ceiling constructions described in the standard specifications are intended to prevent the rise to dangerous temperatures in the inter-joist spaces. So far as recorded in the several tests, the averages are:

	1 hour	2 hours	3 hours	4 hours
1.....	530	742	...	...
2.....	441	719	...	...
5.....	551	686	767	850
7.....	835	...	...	...
9.....	135	183	196	201

In considering No. 9, it must be kept in mind that these figures are for the comparatively heavy channel and not for the inter-joist space, and furthermore that the ceiling protection was three inches thick of the most efficient insulating material used in the building industry for fire protection.

The Fire Record.

In the matter of fire resistance the record of actual fires does not contribute materially to our knowledge, as the following enumeration will show. The list, a remarkably short one, considering the extent to which steel joists have been used, is as complete as an energetic inquiry could make it.

(1). On December 17, 1922, a fire occurred early in the morning in a two-story school building at Belleville, New Jersey. The original building was about 80 ft. by 40 ft. in area, to which additions had been made at various times, the area at the time of the fire being about 14,000 square feet. The roof over the entire building was of wooden construction. In the latest addition, covering about twenty per cent of the area of the building, the floor construction of the first and second stories consisted of six-inch steel joists, sheet-metal type. These joists supported a two-inch cinder concrete slab on metal lath in which wooden sleepers were buried, to which $\frac{7}{8}$-inch flooring was attached. The ceilings were $\frac{3}{4}$-inch hard plaster on metal lath clipped to the joists. In the older parts of the building wooden joists were used in the floor construction. Practically all of the upper part and fully fifty per cent of the first story of the building was destroyed. Some fire got into the first story of the newest section, "but there apparently was no great amount of fire in that section."

In the second story the wood flooring was almost completely burned away and the fire consumed a good part of the wooden sleepers. Outside of this there was no fire damage to the steel joist floor construction. "There is no doubt that this form of floor construction prevented the fire from spreading into the first floor and basement" of the new section. The late Ira H. Woolson, commenting on this fire, stated: "This fire, in my opinion, was not in any material sense a demonstration of the fire-resisting properties of metal joist construction."

(2). A fire which occurred January 15, 1929, in a building under construction at Atlantic City, New Jersey, is described by a representative of the manufacturer of the joist, truss type, used in the floor construction, as follows:

> Due to carelessness on the part of some workman in throwing either a lighted cigarette or a match into a barrel of waterproofing, on the fourth floor of this building, the said waterproofing, consisting of very flammable ingredients, namely naptha, tar, etc., immediately flared up, setting fire to some boxes and other flammable matter. The result was that an intensely hot fire was immediately raging under the fifth floor slab. The ceiling lath had been attached to the fifth floor joists, but the ceiling was unplastered. The ceiling lath was very soon reduced to a mass of twisted metal. The paint was all burned off of the bar joists, and the under side of the fifth floor slab subjected to a very high temperature.
>
> No cracks resulted in this concrete slab. The fire burned for a period of about forty-five minutes until the firemen reached the site, got their hose lines stretched to the fourth floor, and succeeded in getting the fire under control. The following day a load test was placed upon the floor slab, where the fire had taken place, equal to the rated capacity of the slab. There was absolutely no deflection in any of the joists. The results were very convincing and satisfying to everyone connected with this building project.

(3). Of the fire that occurred in the Hunt Garage at Rochester, New York, in 1927, little definite information is available. The building was two stories in height; no cellar. The floor construction consisted of steel joists, truss type, supporting a concrete floor slab. "The roof was wood deck on steel trusses." "The fire occurred on the second floor, bringing down the wood roof but doing comparatively little damage to the second floor."

(4). A fire, reported in 1925, at the Greenbrier Military Academy, Lewisburg, West Virginia, started in and destroyed one wing which was "two stories in height and of frame, brick veneered construction." The fire did not enter the newer wing in which the floors were of steel joist construction, sheet-metal type, as the fire was successfully fought from the connecting stairway tower, which was also of metal joist construction, with unprotected openings on all floors. Although the stair tower was subjected to considerable heat, it was not considered "a fair fire test of this type of construction." There was no "real severe exposure of the floor construction."

(5). At Lansing, Michigan, a fire occurred, March 14, 1924, in the Bauch Building, a ten-story business building, of which the lower six stories were of concrete joist construction, and the top floor, a later addition, were of

steel joist construction. The fire originated in the basement and spread to the upper stories through an unprotected pipe shaft. "The loss paid on the building, damage to wood trim, glass, wiring, decorating, etc., amounted to $16,375.34, and the content loss was $5,815.83," which, while considered a high estimate by the fire chief, in so small a building (20 ft. by 100 ft.) is regarded as indicating an extensive burnout of trim. The stories affected by fire are not mentioned in the information furnished.

(6). A severe fire, in which steel joists were involved to some extent, occurred in December, 1925, near Ypsilanti, Michigan, when a three-story school building, 17,500 square feet in area, with brick-faced hollow tile walls, was completely gutted. Only the corridor floors were of steel joist construction, sheet-metal type. "This example has very little, if any, bearing on the question of the fire-resistive qualities of the material."

(7). In December, 1927, a fire occurred in the New Subiaco Abbey, Subiaco, Arkansas. The building was three and four stories high, with heavy stone walls, built in the form of a hollow square. In the newer portion steel joists, sheet-steel type, were used to some extent in the floor construction, wooden joists having been used in the older section. The fire started in the basement of the older part, burned out that part and communicated to the newer part by means of the roof, which was of frame mansard construction. In describing the damage the builder stated that "the metal joists that suffered during the fire were those that had no protection from the top, that is, those that had no floor on them, . . . nearly all the floor that is now left is that covered with two inches of concrete and lath."

(8). A fire was reported at Tulsa, Oklahoma, in a two-story automobile salesroom and service station, the second floor of which was constructed of 2½-inch concrete on expanded metal on unprotected steel columns and joists. The fire in the first story brought down seventy per cent of the second floor, permitting the blaze to ignite the roof and practically gutting the entire building.

With the possible exception of the second case, the Atlantic City fire, the circumstances of the fire or the inadequate information concerning these fires preclude definite conclusions on the ability of steel joist floor construction to resist a serious conflagration.

Field of Use of Steel Joist Construction.

Considering the materials used for steel joists, their design, the processes of fabrication, the methods of erection, and their behavior under tests for strength and fire resistance, as hereinbefore outlined, it may be asked to what purposes are they more especially adapted; do they offer any advantages over other forms of construction; to what extent, if any, should their use be limited?

As a substitute for wooden joists, there would seem to be no real objection. Within the floor spans ordinarily used in building construction, wooden

joists are probably still more economical. The fact that they are made of incombustible materials may be an advantage when the occupancy constitutes a low fire hazard; but it is doubtful whether unprotected steel joists, or even ceiling protected nailer-joists with wooden floor decks, as quite generally advocated, would suffer less than wood in fires of equal intensity. Steel joists are stiffer, that is, they deflect less under a given load than wooden joists of the same depth and strength; vibration, however, is more noticeable. The shrinkage that wooden joists are subject to, which may or may not be objectionable, is avoided by the use of steel joists.

It is in the larger buildings—those for which economy would, in any case, dictate a steel supporting frame—that decided savings in cost may be effected. According to a study made by Professor R. A. Caughey, of Iowa State College, in 1927, the cost of steel joist floor construction averages about seventy per cent of that of other usual types of fire-resistive floor constructions. This study further showed that the weight of the steel joist floor construction in about sixty-five per cent of the lightest, and about forty per cent of the average weight of the other six forms of floors studied. This means that the supporting steel frame would require a much smaller tonnage and the foundations may be lighter than ordinarily necessary. Other items that tend to reduce cost of construction are the absence of forms, the avoidance, to a large extent, of riveting or bolting, and consequently the saving of time and labor. No heavy equipment is necessary for the installation of this form of construction.

It is in the field of fire-resistive construction that the industry hopes especially to enlarge its usefulness. Even though it is held that the particular fire-resistance ratings fixed by the standard specifications are not fully justifiable, it must be admitted that the floor construction consisting of steel joists protected by a properly constructed ceiling of cement mortar, gypsum plaster or gypsum blocks and supporting a floor deck of suitable concrete undoubtedly has a high value as fire-resistive construction. Its use, as an effective contribution in fire protection and prevention, should be encouraged. Fire-resistive construction in the past, due to unnecessarily severe requirements of building laws and insurance rating schedules, has been economically impracticable. It is just as illogical and unreasonable to require a floor to be designed to meet effectively a greater fire hazard than that involved in the occupancy of the building, as to require such floor to be stronger than necessary to support safely the loads that may be imposed. The requirement for a four-hour fire-resistance for floors, heretofore prevalent, has been a decided deterrent to the wider use of fire-resistive construction in residence buildings and other buildings of light occupancy and low fire hazard.

As ordinarily designed, steel joist floor construction is suitable only for uniform and reasonably fixed loading. Its use is not recommended for garage

floors where the loads are movable and where, especially when truck storage may be expected, high concentrations are almost certain to occur. Under certain not unusual conditions, the effect of the concentrations may be equivalent to a uniformly distributed load of five times that for which the floor is designed. It is quite possible so to reinforce the construction, particularly the bridging, that these overloads are safely provided for, but it probably would be economically prohibitive.

Rigidity of Steel Joist Construction.

The lack of rigidity in buildings of steel joist floor construction has been the subject of some discussion. It is held by the advocates of the construction that the joists should not be rigidly secured to the supporting structural elements. It is pointed out that "in the case of fires, the greatest part of the damage is due to the expansion of structural members," and that in those fire tests in which the floor was restrained and no provision made for free expansion of the joists, there was distortion as a result, and that therefore in actual practice the joists should be simply supported, allowing some freedom of movement. The standard specifications provide that when the height of a building exceeds twice the least dimension of the base, each joist shall be welded to the steel work. It is evident that this provision would permit buildings of considerable height in which the floors would not contribute to the rigidity of the building. In support of this policy it is argued that "the frame should be designed to carry all wind load without assistance from the floor construction." This conclusion ignores the existence of horizontal torsion induced by high winds to counteract which additional construction would be necessary, the cost of which would probably exceed that involved in utilizing the floor for the purpose by rigid connection to the frame. Mr. Burton has truly said, "When rigidity becomes an essential factor we must sacrifice the fire expansion." It is now also recognized that the comfort of occupants of buildings demands rigidity. The necessity for rigidity in regions subject to earthquake disturbances is reflected in the insurance rating, which places the construction in the same category as ordinary wood-joisted construction.

National Board Building Code Provisions on Steel Joists.

In the building code recommended by the National Board of Fire Underwriters, fifth edition, there are no specific limitations placed on steel joist floor construction. There are, however, certain provisions that actually restrict its use. To be regarded as "fireproof," "each beam, joist or girder constituting part of a floor construction shall be individually protected by fireproofing materials." Irrespective of the fire-resistance rating that the steel joist construction may develop, by reason of the impracticability of encasing the individual joists, it is automatically classed as "semifireproof-construction," assuming that a two-hour fire-resistance rating is conceded to it. Of this type of construction, public garages are limited to seventy-five hundred square feet

Fig. 11. The 35-story Grant Building, Pittsburgh. The tallest building using steel joist floor construction throughout.

in area, and buildings of other occupancies to ten thousand square feet, subject to permissible increases in area if sprinklered, if limited to one story in height, or if located outside the fire limits.

The height limitation fixed for "semifireproof-construction" is seventy-five feet; except that for "storage buildings," that is, garages, stables, hangars, storage warehouses, freight depots, the limit is fifty feet. Whether these more or less arbitrary limitations are reasonable is perhaps debatable. It has already been pointed out that as buildings increase in height rigidity becomes important. While welding, riveting or bolting of steel joists to the supporting frame no doubt adds stiffness, it can hardly be claimed that the thin floor deck and the flexible ceiling of this floor construction are of great service to prevent horizontal distortion. Security against damage or destruction by fire also increases in importance as the building increases in height. The difficulty of coping with fire at high elevations is greater; the result of failure in any of the structural elements is more serious; the escape of occupants is less certain. On the other hand, it is maintained that if a form of construction is designed to resist a given hazard, and is capable of doing so, it makes no difference whether this hazard is met in the second story or the twentieth story of the building. A wider experience with steel joist floor construction will possibly justify modification of the restrictions now placed on its use. The steel joist of today, properly installed, is a comparatively recent product. The standard specifications became effective February 1, 1929. The fire record is limited, and there has been no fire test on the construction as now installed in buildings that can be regarded as official or conclusive.

Extent of Use.

Steel joists command a large field of usefulness. The average annual production exceeds 50,000 tons. Literally thousands of buildings are being erected in which they find application. Such cases are now being noted in the maps published by the Sanborn Map Company. While no definite information of the number of buildings employing them, or of the tonnage shipped for this purpose has been made available, the figures to which access has been had, covering a two-year period, indicate the proportionate application to buildings of various occupancies as follows:

	No. of Buildings (Percentage of Total)	Tonnage (Percentage of Total)
Schools, colleges, academies and buildings in connection therewith	30	36
Garages, factories, hangars, sheds and miscellaneous buildings	21	16
Stores and office buildings	16	14
Apartments, hotels, residences	15	17
Theatres, churches, auditoriums, dance and drill halls, and other public buildings	10	8
Hospitals, asylums, institutions	8	9

The average tonnage used in these buildings is about 25, representing a floor area of 15,000 square feet or more, with educational buildings leading in average size. Of these buildings it is estimated that about ten per cent were of such magnitude that, under the provisions recommended in the National Board Building Code, "fireproof construction" would be required. One of the largest operations to use steel joists throughout is the Rockland State Hospital at Orangeburg, New York, a group of buildings, one to four stories in height, in which over 600 tons were used. The tallest building using joists, truss-type, is the Grant Building at Pittsburgh, Pennsylvania, a 35-story office building (Fig. 11). In the Metropolitan Building of Toronto, Ontario, 21 stories in height, joists of the sheet-steel type were used. As might be expected, the largest demand for steel joists comes from the region in which fabrication takes place. The state of Ohio leads as the largest consumer, followed by New York, Pennsylvania, Michigan, Illinois, and Wisconsin. These six states use more than fifty per cent of the production. Only about two per cent of the product goes beyond the Rocky Mountains.

Acknowledgment is hereby made to the various manufacturers of steel joists and especially to Mr. Frank Burton of Detroit, Michigan, for courtesies in furnishing information for the preparation of this article.

A Non-Sparking Concrete Floor Surface.

One of the safety requirements laid down for the powder magazines constructed at the new naval ammunition depot, Hawthorne, Nev., was that the concrete floors should have non-sparking surfaces. The importance of this requirement is apparent from the fact that 71 tons of high explosives are stored in each magazine unit and the ultimate total for the depot as a whole is about 6,000 tons. The non-sparking requirement was met by treating the thoroughly cleaned concrete floor surface with a solution of 3 lb. of castile soap completely dissolved in 4 gal. of water. This solution was applied liberally to the surface at a temperature not less than 200 degrees F. and worked into the surface with a long-handled brush in a manner to remove air bubbles, without forming a lather. After thorough drying, the floor was treated with a solution of ½ lb. of potassium alum dissolved in 4 gal. of lukewarm water. When this application had dried, another complete treatment of soap and water, followed by alum and water, was repeated. After drying again, the floor was finally washed to remove the light coating of potash which formed on the surface. On floors treated in this way it was practically impossible to draw sparks by striking the concrete surface with hard objects.—*Engineering News-Record.*

Starrett-Lehigh Building Fire, New York.

Report by New York Board of Fire Underwriters,
(Member N.F.P.A.).

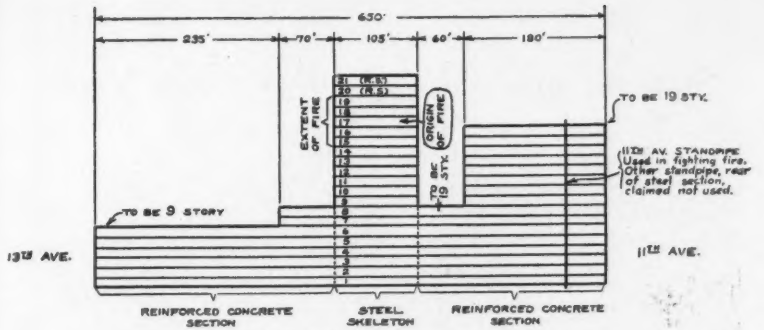
A spectacular fire, originating on the seventeenth floor, destroyed five floors of scaffolding and form work in a 21-story section of the Starrett-Lehigh railroad warehouse in New York City shortly after 5:00 P.M. on June 29, 1931. This latest "building under construction" fire, like similar fires in the Sherry-Netherlands Apartment Hotel, the Riverside Church, the Æolian Building, and the Pennsylvania Hotel, demonstrates again the potential hazard of the use of combustible material for construction operations, particularly in tall buildings. Fires of this kind can be expected so long as quantities of readily ignitable and combustible materials are used during the construction period.

The absence of an effective standpipe system and a proper stairway to the upper part of the building where the fire originated caused considerable delay and added to the difficulties in fighting the fire. These handicaps, together with the example furnished by burning wooden forms, scaffolding, chutes and temporary enclosures, clearly indicate the importance of following the suggestions made by the N.F.P.A. Committee on Construction Operations in the pamphlet "Recommended Good Practice Requirements for Construction Operations."

Description of Building.

The building is to be occupied as a freight terminal and for manufacturing. It occupies the entire block bounded by Eleventh Avenue, West 26th Street, West 27th Street and Thirteenth Avenue, with a total area of 128,000 square feet. It is of reinforced concrete, mushroom column type, except for a central portion of steel skeleton construction on the 26th Street side housing elevators. The greater part of the reinforced concrete portion of the building is to be 18 stories in height when completed, while a smaller portion is to be nine stories high. The steel section covers an area of 8,250 square feet and at the time of the fire had been erected to its total height of 19 stories and a two-story roof structure, a total of 296 feet above the street level. Directly behind this section a similar section of concrete is to be erected.

Because of the large area of the building and its differing types of construction, the structure was being erected in separate units. At the time of the fire the heights of the several units varied. The Eleventh Avenue section, erected first, had reached a height of about 17 stories. The reinforced concrete section at the rear, for a space of 60 feet to the east of the steel skeleton



STARRETT-LEHIGH BUILDING
26TH ST. ELEVATION. TIME OF FIRE.

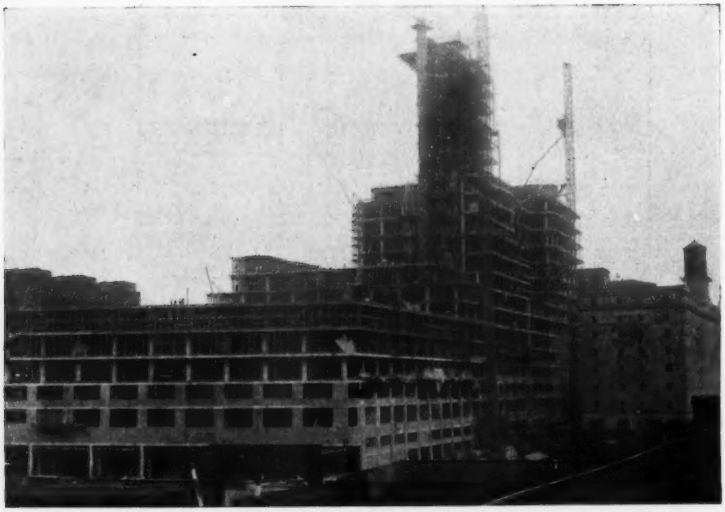
section, had been erected only to the ninth floor. The steel skeleton section had, as before mentioned, reached its full height of 19 stories and roof structure, while on the Thirteenth Avenue side the concrete portion had been erected to about the seventh floor.

From the foregoing it will be seen that the steel skeleton section of the building extended about thirteen floors above the adjoining sections. The concrete floor arches in the steel section had been completed to the 14th floor, but the wood forms had not been removed above the 12th floor, while wood forms were in place on the 15th, 16th, 17th, 18th and a portion of the 19th floor awaiting the pouring of the concrete.

Private Fire Protection.

When the building is completed there are to be five standpipes supplied by gravity tank and fire pump. A complete system of automatic sprinklers is also to be provided. At the time of the fire, however, the chief protection available was the standpipe system, which was being installed as the building progressed. This system was not in the steel skeleton section where the fire occurred, but in the adjoining concrete section facing Eleventh Avenue. In this portion of the building, approximately 170 feet east of the steel section, there was an 8-inch standpipe riser in a stair shaft extending to about the 17th floor, where an emergency control gate valve was located. Two other 8-inch risers extended up through the concrete section immediately at the rear and to the north of the steel skeleton section. These latter risers were carried only to the ninth floor level, where they were temporarily capped.

All the standpipe risers were cross-connected and had outside siamese fire department connections. The cross-connection piping was below the first floor and underground, as there is no basement under this part of the building. Emergency control gate valves were installed in all lines, and emergency $2\frac{1}{2}$-inch hose outlet valves were installed in the Eleventh Avenue standpipe



General view of Starrett-Lehigh Building, showing state of completion at time of fire. The tower in the background is the steel skeleton section where the fire originated.

at the first floor. No water supply other than that available from fire department hose streams through the outside siamese connections was available.

A number of five-gallon pump type hand extinguishers were distributed throughout the building, but it is unlikely that any of them were located on the upper floors of the steel skeleton section. It is doubtful, however, if any first aid appliances would have been effective, for the fire when discovered was probably well beyond the incipient stage. The builders employed watchmen, but they were not supervised and their value was therefore limited.

Story of the Fire.

The fire was first noticed on the 17th floor of the steel skeleton section and had gained considerable headway before it was discovered. Although men were working in the building at the time, the first alarm was sent in by a pedestrian from a fire alarm box located three blocks away at 23rd Street and Thirteenth Avenue. This alarm was received at 5:16 P.M., and was followed by a second alarm at 5:48 P.M.

The fire apparently had its origin in a wooden refuse chute which extended in a zigzag fashion down through the steel skeleton section of the building. The chute was about 27 inches square and was constructed of ordinary wood planks 2 in. by 9 in. Openings with hinged doors were provided on each floor. Waste material, consisting of small pieces of wood and building refuse, filled the chute to the seventh floor level. The inside of the chute from the seventh floor up was badly charred, indicating that the chute,

The fire had its origin in a wooden refuse chute which zigzagged up through the building. This chute acted as a flue, conducting the fire from its point of origin at the seventh floor level to the seventeenth floor, where it extended to the wooden forms supporting the floor arches.

acting as a flue, carried the fire upward to the 17th floor, where it extended to the wooden floor-arch forms.

The fire was discovered about three-quarters of an hour after the steel workers had quit at 4:30 P.M. The cause of the fire could not be definitely determined, but it seems probable that it was due to a discarded cigarette. Other possible fire causes were two rivet forges, an acetylene cutting torch, a gasoline hoisting engine, and an electric motor. An investigation indicated that none of these was a probable cause.

The fire spread rapidly from the chute to the wooden forms and planking on all floors above the 17th and then broke out on the floors below, due either to direct contact of combustible material with the burning chute or falling brands. In a short time all the wood forms, planking and other combustible material on the 15th to 19th floors were in flames. Brands fell into West 26th Street and the area on the south side of the building. Three separate fires were started in a lumber yard two blocks south of the fire, and a burning plank fell through a third floor window in a near-by warehouse, igniting merchandise and causing two sprinklers to operate.

How the Fire Was Fought.

Upon the arrival of the first fire company, they were told by the operator of the hoist in the steel skeleton section that he would take them to the floor on which the fire was located. Thereupon the captain of this company with some of his men and several lengths of hose were taken to the 17th floor. Not finding a standpipe on this floor, the captain ordered the hose taken down to the ninth floor standpipe line. After this was done, it is reported that the hoist gave way and fell to the first floor, leaving some of the firemen stranded on the 17th floor. By this time the fire began breaking out on the floors below and the firemen had to slide down the steel columns to escape.

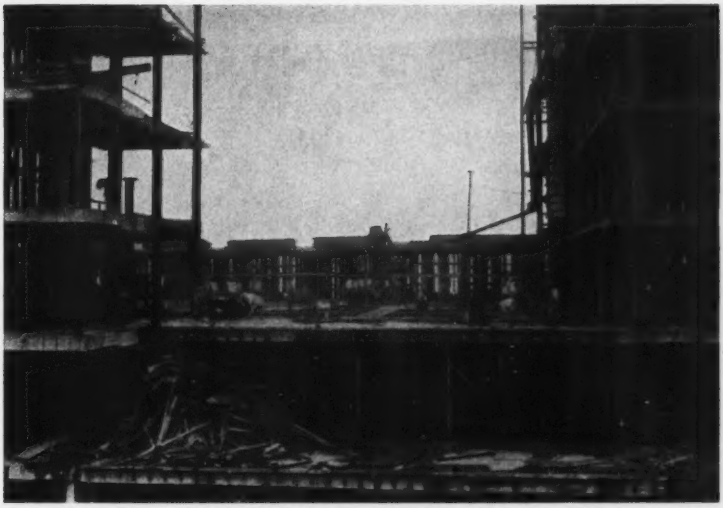
The firemen then attempted to make connections to the upper floor outlets of the standpipe in the Eleventh Avenue portion of the building, but could not do so because of the absence of nipples at these outlets. Eventually, after a delay, nipples were obtained from the plumber and lines were stretched to the edge of the roof of this portion and a stream directed upon the fire across the 60-foot space (see diagram) that separated the two sections. Another line was taken from this standpipe on the ninth floor and stretched to the base of the steel portion. Still another line was stretched from a fireboat in the Hudson River, up across the west end of the building to the base of the steel skeleton section.

An attempt was made by the fire department to obtain water from the two standpipes in the nine-story part of the concrete portion of the building, directly in the rear and north of the steel skeleton portion, but it was found that water in these standpipes would not rise higher than about the sixth floor. This was due to a failure of a leaded joint in a horizontal underground cross-connection. As soon as the break was discovered, the emergency control gate valve at the base of the Eleventh Avenue standpipe was closed and connection to this standpipe made directly to the first floor outlet valves provided for that purpose. From this time the standpipe was operated independently and worked efficiently.

As the building is located in the high pressure district, water for the standpipes was obtained by making direct connections with the high pressure system. At the high pressure station on Gansevoort and West Streets, pumps were started at a pressure of 125 pounds, increased to 150 pounds at 5:25 P.M., and 175 pounds at 5:50 P.M. The pumping station continued to operate until 2:36 A.M. the following morning, when two fire department pumpers were substituted.

Damage.

The extent of damage to the building was considerable. Many of the lighter steel beams and girders were twisted and deflected so as to require replacement, although the heavy steel columns and main beams were apparently undamaged. The freight elevator motor and its switchboard on the



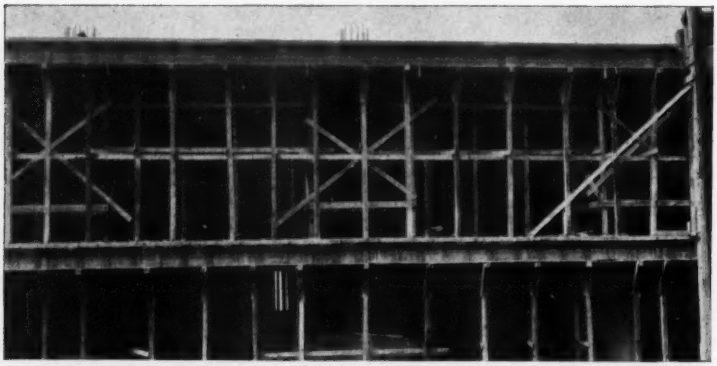
This picture shows the steel skeleton where the fire occurred at the left; at the right the concrete section, and in the center the temporary court across which hose streams were directed. Note large amount of wood used in construction, and careless disposition of wood refuse and waste in left foreground.

17th floor, near the refuse chute, were badly burned, as were also three motor generator sets and a gasoline hoisting engine located on this floor. All wood forms, planking, ladders and refuse chute above the 15th floor were practically destroyed. Water damaged electrical and other equipment in the basement. The total loss on the building was $94,000.

Conclusions.

The lessons of this fire differ but little from those of previous fires in buildings under construction. The features that stand out most prominently are the excessive amount of combustible material in the building; the absence of adequate fire protection equipment for fighting fire in the upper stories; and the danger to surrounding property from falling brands and sparks.

Too much emphasis cannot be given to the severe hazard created by the use of large quantities of combustible lumber for shoring, scaffolding, enclosures, etc. Just so long as these materials are used in the construction of tall buildings, this type of fire may be anticipated. The interior wooden refuse chute zigzagging up through the building created a natural flue and was a distinct hazard. Chutes of this character often become filled with wooden scraps and rubbish awaiting their removal. A discarded lighted cigarette or a match is all that is needed to start a serious fire, which will extend rapidly through the building and defy the efforts of first aid equipment to extinguish



View of reinforced concrete section, showing the combustible shoring used to support equally combustible wooden floor-arch forms.

it. Chutes should be made of flameproof wood, or better still, of incombustible material and should be kept clean at all times.

Had the fire in the steel skeleton part extended to the reinforced concrete section, where a vast amount of lumber was used for forms, form supports or shores, the damage would have been very severe. The amount of lumber used in the construction of these sections was amazing. A great amount of this lumber could have been eliminated by the use of metal shores or supports.

Had this structure contained an effective standpipe system and proper stairway in the steel skeleton part of the building where the fire occurred, the firemen would not have been handicapped in their efforts to control the fire, and the damage would have been negligible. It should be noted that the "Standpipe Fire Line" rules of the Board of Standards and Appeals provide that in buildings in course of erection, fire lines shall be carried up with each story after the structure reaches the seventh floor, or a height of 85 feet. This rule was not followed, as no standpipes were installed in the steel skeleton section where the fire took place. Standpipes were located in the reinforced concrete portions of the building and eventually will be available for the steel skeleton portion, but the concrete portion had only reached a height of nine stories while the steel skeleton portion had advanced about 12 stories higher.

In an unusual condition as just described, at least a temporary 3-inch standpipe was necessary in the steel skeleton section in order to comply with the standpipe regulations. Leaded connections such as existed at the base of the cast riser in the nine-story section are not standard. This faulty connection has been replaced and the joint again leaded, but installed with tie rods. Rules of the Board of Standards and Appeals provide that all joints be either screwed or flanged.

The requirement for the installation of emergency control gate valves in the base of the individual standpipes proved of great value in this fire. When the section of standpipe held together by leaded joint in the cross-connection in the basement pulled away from its fitting, this emergency control valve at the base of the standpipe in the Eleventh Avenue portion of the building was immediately shut and the standpipe was thus enabled to operate efficiently.

Flying brands caused considerable damage to the adjacent Baltimore & Ohio Warehouse building, and also slightly damaged the lumber yard two blocks distant. Luckily the absence of a strong wind minimized the hazard to the surrounding properties.

It may not be amiss to call attention to the fact that these fires go beyond the actual property destroyed by delaying completion of the building, with consequent loss of revenue. Important business projects, contingent upon occupancy of the structure at a given date, may thus be seriously deranged even by a fire causing a relatively small direct loss. Strict compliance with the requirements for safe construction as recommended by the N.F.P.A. Committee on Construction Operations would do much to reduce the number of these avoidable fires.

Aftermath.

Early last October a fire originating in flammable falsework damaged the nearly completed State Education Building in Harrisburg to the extent of about $750,000 (QUARTERLY, Jan. 1931, p. 330). In March the Pennsylvania Supreme Court placed full responsibility for the loss upon the contracting firm which was doing the work. An immediate receivership resulted and work was suspended upon all other contracts held by this company, including four major building operations totaling more than $3,000,000 in value, as well as several smaller jobs. Query: How much will the neglect of adequate safety precautions cost the contractor, his creditors and the owners of the other buildings with which he is connected?—*Engineering News-Record.*

Tank Truck Fire, Edmonton, Alberta.

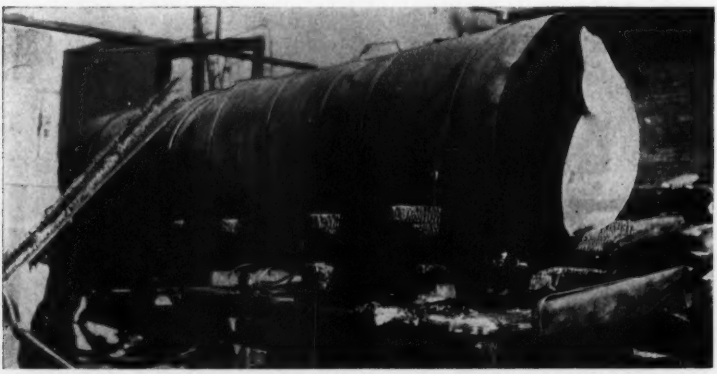
By J. Booth, Edmonton City Fire Marshal,
(Member N.F.P.A.).

The hazard attendant upon the use of an improper and non-standard tank truck for the transportation of flammable liquids was clearly demonstrated by a fire which occurred in a garage at Edmonton, Alberta, on June 11, 1931, resulting in the total destruction of the building and its contents, including the offending tank truck.

The tank truck which was directly responsible for the fire had been constructed locally to transport gasoline from the Turner Valley oil field, about 260 miles from Edmonton. The truck, a six-wheeled affair, consisted of two tanks on a wooden timber frame, the forward end of which was supported on the rear of a small automobile truck and the rear on a trailing axle. A ground chain was attached to the chassis of the truck, but with the wooden timber frame there was no electrical connection with the tanks and the chain was of no value. It is obvious that little or no thought for fire safety was given in the construction of the truck.

Story of the Fire.

The fire occurred on a hot June day. The truck had transported a load of gasoline to Calgary prior to coming to Edmonton, at which time there were 1141 gallons in the two tanks. The fill-pipe of the underground tank at the garage of McNeill's Van and Storage Company, Ltd., in Edmonton was



This home-made tank truck, with tanks mounted on a wooden frame with no ground connection, was responsible for a fire that destroyed a garage in Edmonton on June 11, 1931. A grounding chain had been provided, but this was attached to the automobile chassis and not connected to the tanks.

Ruins of the garage with the remains of the tank truck in the rear. The truck was driven into the garage to fill an underground tank, using a makeshift gasoline hose and funnel.

located inside the building instead of in a proper location outside. The truck was driven into the garage to deliver gasoline to the underground tank.

Due to the fact that he had lost his tank hose on the trip from Calgary to Edmonton, the driver attempted to use a metal-lined rubber-covered hose which he took from a gasoline pump in the garage. The nozzle on the hose was too large to go into the fill-pipe opening, so a funnel was placed therein and the gasoline allowed to run into the funnel.

About 300 gallons of gasoline had been emptied into the tank when an explosion occurred, followed by a fire which spread rapidly through the one-story brick garage. Three men in the garage at the time fortunately escaped without injury. Six motor trucks, five taxis and two pleasure cars were destroyed, together with the tank truck, and the building was severely damaged, only the walls remaining.

Static electricity is given as the cause of the fire. With the makeshift hose and funnel, there was every opportunity for ignition of gasoline vapor by a static spark. The spark may have been from static electricity accumulated in the tank during the long trip and not removed by any grounding facilities, or from static electricity generated during the flow of gasoline through the hose and funnel, which may not have been in proper metallic contact. Whatever the immediate cause of ignition, the non-grounded substandard tank truck, the makeshift tank-filling arrangement, and the conduct of the tank-filling operation in the building were clearly responsible, any one of the three factors alone being sufficient to account for the fire.

Protection Against Exposure Fires.

Protection against exposure fires presents a difficult problem, because of the uncertainty as to the probable severity of the exposure and the extent to which public fire protection can be relied upon, and because of the practical objections of cost, appearance and interference with operating convenience sometimes met in the installation of the several forms of protection available. The present record is a compilation of 897 exposure fires recorded in the files of the N.F.P.A. Department of Fire Record, designed to present a typical cross section of actual fire experience analysed to show the behavior of the different forms of protection under varying conditions. Exposure fires in unprotected buildings, about a third of the total number in the record, have been included to give a basis of comparison.

Exposure fires for the purposes of the present record are considered as external sources of fire (usually other burning buildings), where the fire may be communicated to the exposed buildings by radiated heat, flame or hot products of combustion entering window openings or igniting combustible exterior surfaces. Fires started by sparks from bonfires and like causes are not included in the present record. Likewise general city conflagrations are not included, except as individual buildings in the path of a conflagration are subjected to conditions comparable to the usual type of exposure fire.

Fires in mercantile and industrial buildings constitute the bulk of this record, as it is in the mercantile and industrial districts that the more severe exposure hazards are principally found. The exposure hazard in residential sections is found chiefly in areas where dwellings of light frame construction are built close together or combustible roofs predominate. This hazard is well recognized and can readily be controlled through the enforcement of adequate building regulations; further discussion of this phase of the exposure hazard is considered unnecessary in this article.

The hazard of exposure fires in mercantile and industrial sections, while partly dependent upon building code requirements for better construction, may be safeguarded by the protection of all combustible exterior surfaces and window openings. Such protection may be in the form of open sprinklers, wired glass windows, shutters, fire doors and automatic sprinklers or a combination of these. Each, as is indicated by this record, has proven its value and demonstrated its effectiveness in preventing serious loss, and, under certain circumstances, has failed due to inherent limitations.

Fire doors have not been considered in this discussion, for their function is primarily to prevent the spread of fire through the interior of buildings

Wm. E. Patterson.

An exposure fire starting in a freight car swept up the metal-clad frame elevator shaft on the outside of this Pittsburgh warehouse and caused serious damage on the top floor before it was checked.

rather than to safeguard against external exposure. In the fires analysed in this record, however, there were a number of instances where fire doors were a factor in conjunction with other types of external exposure protection in preventing the spread of fire from adjoining buildings.

The problem of the most suitable type of protection for a given exposure is complicated by the many variable factors which are involved. Every exposure fire is different from the next. Wind currents, weather conditions, the combustibility of the exposing structure and its contents, the availability and efficiency of private or public fire-fighting facilities, and the promptness with which the alarm is given are all variable factors having a bearing on the probable intensity of the fire. Other factors, more determinable in advance, are distances between exposures, and the construction, height and arrangement of the building exposed.

The Chicago fire of March 15, 1922, in which the fifteen-story fire-resistive Burlington Building was severely damaged from an exposure fire across an 80-foot street, created a great deal of interest, as did a round table discussion on protection against exposure which took place at the 1922 annual meeting of the N.F.P.A. (Proceedings 1922, p. 252.) At that meeting and in later discussions it was brought out that there was no one simple solution to the problem, and that there was a need of a careful study of past experience

The Burlington Building, Chicago, was severely damaged by an exposure fire across an 80 ft. street on March 15, 1922. This was a modern fire-resistive building, but had plain glass windows on the exposed side. Fire entered simultaneously on the upper eight floors, destroying the interior trim and contents, which involved a loss many times the value of the building itself.

When this Springfield, Missouri, theatre was destroyed, fire entered an adjoining hotel of fire-resistive construction through unprotected window openings, damaging the woodwork and furnishings of forty rooms. With proper window protection this severe loss could have been avoided.

in fires and some sort of classification of the various types of protection available. With this in mind a fire record, "Protection Against Exposure Fires," was prepared by the Executive Office of the N.F.P.A. and published in the QUARTERLY for January, 1924 (Vol. 17, No. 3, p. 274). This record was based on a study of 544 fires recorded in the Department of Fire Record up to December, 1923. The present record incorporates the previously published data and the many additional reports of exposure fires that have been received between January, 1924, and September, 1931.

The importance of the problem of exposure fires from a national viewpoint is indicated by loss figures compiled by the Actuarial Bureau of the National Board of Fire Underwriters for the United States for the five years ended December 31, 1929. These figures are as follows:

U. S. Losses Due to Exposure.*
(Including conflagrations.)

Year	Total Loss	Exposure Loss	Per Cent of Total Loss
1925.....	$559,418,184	$76,741,017	13.7
1926.....	561,980,751	67,593,192	12.0
1927.....	472,933,969	56,353,434	11.9
1928.....	464,607,102	51,524,367	11.1
1929.....	459,445,778	46,391,112	10.1

*These figures include 25% for unreported and small losses.

An open street is not necessarily a protection against exposure. This mercantile building in Pittsburgh was destroyed as the result of exposure to a burning tank truck which overturned in the street in front of the store.

In considering the data presented herewith it should be borne in mind that the record is not complete, including but a small proportion of the total number of exposure fires. Many instances, where exposure protection is satisfactory and no damage results, are not reported to the N.F.P.A. Department of Fire Record, and a considerable number of exposure fire reports recorded did not contain sufficient information to be of value in this record. It would appear, therefore, that the data here presented indicate for all types of protection an average efficiency considerably less than that which would be shown if all exposure fires could be included in the record.

The most important factor in the control of exposure fires is the public fire department, for without fire department protection most of the fires which are at present extinguished with small loss would be expected to develop into serious exposure fires, if not general conflagrations. It is not practicable to analyse fire department operations in this study, but the progressive decrease in the percentage of the total loss attributed to exposure in the foregoing table doubtless reflects increasing fire department efficiency, as well as a gradual improvement in building construction and safeguarding of hazards. Protection against exposure fires, as contemplated in this article, is the private protection that comes into play in the occasional instance where the public fire department does not succeed in controlling the exposure fire before it has reached dangerous proportions, owing to delayed alarms, highly flammable contents, inferior construction, inadequate water supplies or other factors. Even in such cases the fire department operations are exceedingly important, and in many of the fires in this record the equipment installed to protect against exposure would not have performed successfully had it not been for supple-

No window protection and a deficient water supply for the large number of heads opened were responsible for the total loss of the Naumkeag Mills in the Salem, Mass., conflagration. The extremely severe exposure was too great for private fire protection when the city water supply failed.

mentary work by the fire department. Similarly, employees organized in private fire brigades may be a factor of great importance, but it is likewise impracticable to analyse their effectiveness on a statistical basis.

This record has been separated into a number of sections, the first containing general tables showing the experience with the various types of protection, and the subsequent sections discussing in some detail the performance of specific types of protection together with summaries typical of their success or failure.

The first table indicates the type of exposure protection provided, and summarizes the loss experience by types of protection and construction of buildings exposed. As will be shown later, this table is not entirely indicative of the relative efficiency of the various types of protection but gives a general picture of the situation.

The heading "No or Slight Loss to Building" does not necessarily mean that the protection provided was entirely successful, as fire department hose streams and the severity of the fire may have been equally important factors in minimizing the loss. Under "Partial Loss to Building" may be both fires classed as window protection successes or failures. A fire where the window protection held but fire entered the building through the roof or on an unprotected side would be placed in this class. A fire where the window protection failed but where inside sprinklers prevented heavy loss would also be placed in this class. In other words, an attempt has been made to show the relative loss experience on a basis comparable with that used in analysing fires in sprinklered buildings, where a loss in a sprinklered property is recorded as such, even though it may not be due to any failure of the sprinkler equipment to perform its designed function.

Effect of Various Types of Protection Against Exposure Fires.

Frame Buildings.

Protection	No or Slight Loss to Building	Partial Loss to Building	Heavy or Total Loss to Building	Total No. of Fires
Unprotected	12	35	88	135
Sprinklered	7	36	19	62
Sprinklered – Open Sprinklers	20	22	10	52
Sprinklered – Wired Glass	2	0	0	2
Sprinklered – Tin-clad Shutters	0	1	0	1
Sprinklered – Iron Shutters	0	2	0	2
Sprinklered – Open Sprinklers – Tin-clad Shutters*	1	0	1	2
Open Sprinklers	2	0	0	2
Wired Glass	3	1	0	4
Tin-clad Shutters	0	1	1	2
	47	98	119	264

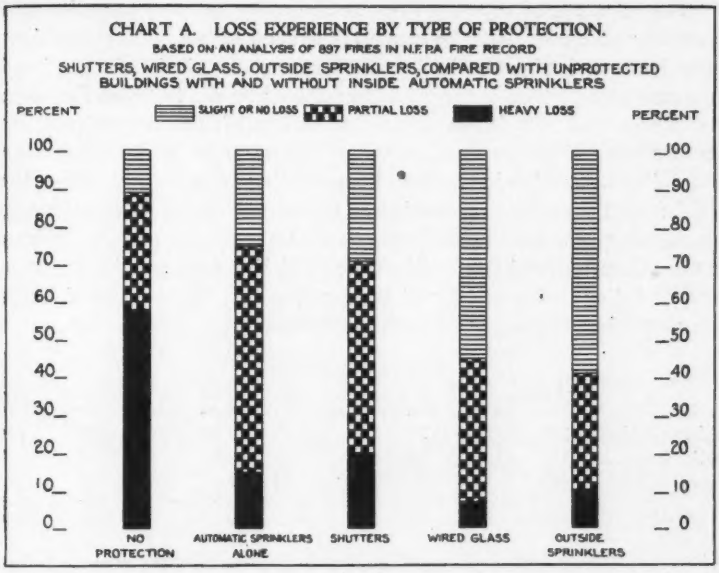
Brick or Fire-Resistive Buildings.

Unprotected	18	49	65	132
Sprinklered	63	131	22	216
Sprinklered – Open Sprinklers	34	18	3	55
Sprinklered – Wired Glass	28	30	4	62
Sprinklered – Tin-clad Shutters	8	28	5	41
Sprinklered – Iron Shutters	0	8	3	11
Sprinklered – Shutters (part iron and part tin-clad)	1	0	0	1
Sprinklered – Open Sprinklers – Wired Glass	8	4	0	12
Sprinklered – Open Sprinklers – Tin-clad Shutters	6	2	2	10
Sprinklered – Open Sprinklers – Wired Glass – Shutters	1	0	0	1
Sprinklered – Wired Glass – Tin-clad Shutters	2	2	0	4
Open Sprinklers	12	2	0	14
Open Sprinklers – Wired Glass	3	0	0	3
Open Sprinklers – Wired Glass – Shutters	1	0	0	1
Wired Glass	18	9	5	32
Wired Glass – Tin-clad Shutters	2	6	0	8
Wired Glass – Iron Shutters	1	0	0	1
Tin-clad Shutters	5	3	3	11
Iron Shutters	0	1	5	6
	211	293	117	621

No Data As To Construction.

Unprotected	0	1	3	4
Open Sprinklers	4	0	0	4
Sprinklers – Wired Glass	1	0	0	1
Wired Glass	3	0	0	3
	8	1	3	12
Grand Total	266	392	239	897

*In subsequent tables this is considered as sprinklered – open sprinklers, for on a frame building the shutters add little if anything to the protection.



To permit a more convenient comparison of the various types of protection a chart (A) has been prepared, showing up the experience of each type without regard to the construction of the building involved, distance from exposing fire or other exposure protection provided.

The chart indicates that open sprinklers are the most effective window protection, followed respectively by wired glass and shutters. The showing of automatic inside sprinklers is indicative of their value in protecting against exposure, but an analysis of the fires recorded shows that in a large number of instances severe water losses were suffered. In most cases the fire entered the building but was controlled inside by the sprinklers. A serious exposure fire is necessarily a severe tax on a sprinkler system, as fire may enter on all floors and open a large number of heads. Twelve of the 41 heavy losses were in conflagrations where a large number of heads were opened and where the water supply was in most cases reduced because of heavy draught by the fire department. Sprinklers are not designed to control exposure fires, and the fact that they were more or less successful in 237 out of 278 cases is a tribute to their efficiency.

As might be expected, only about 10% of the 271 unprotected buildings escaped with but slight or no appreciable loss. The saving of the thirty buildings making up this 10% was for the most part due to the effective work of the fire department or private fire brigades.

The distances of exposing fires, as shown by the accompanying table, apparently have but little effect upon the amount of loss. The proportion of heavy losses and slight or no loss fires appears but little affected by the exposure distance. This is presumably explained by the fact that the number of exposure fires included in this record is limited, that many fires where exposure protection was satisfactory are not recorded and the results are confused by a variation in the size of the exposing fire which cannot be determined from the original reports in the majority of cases. A large fire at a distance may be a more severe exposure than a small fire near by. Were all exposure fires included in the tabulation, and if it were possible to classify them according to the severity of the exposing fire, the showing of distance as a protection would appear much more favorable.

Exposure Distances.

Loss	25 Feet or Less		26 to 50 Feet		Over 50 Feet		Conflagrations		Total Fires
	No.	Per Cent	No.	Per Cent	No.	Per Cent	No.	Per Cent	
Slight or no loss..	207	33.3	24	28.3	21	24.7	14	13.2	266
Partial loss.....	274	44.1	36	42.4	50	58.8	32	30.2	392
Heavy loss.....	140	22.6	25	29.3	14	16.5	60	56.6	239
Total.....	621	100.0	85	100.0	85	100.0	106	100.0	897

Comparison of the Several Types of Protection.

In a comparison of the various types of protection it should be noted that every type has some inherent weakness. Except in the case of automatic sprinklers all the forms of protection in general use depend in some degree upon the human element and, as subsequent data indicate, the human factor is not infallible.

In considering the effect of the human element on the operation of protective devices, wired glass windows show a decided superiority over other types. Windows in buildings of the average occupancy are normally closed and under ordinary circumstances may be expected to be closed at the time of fire. It is significant that in the twenty-six instances where wired glass failed to protect the building, in but one case was the window open.

Wired glass as a fire retardant has much to commend it. It can be used on all classes of buildings and on all sides. In addition to being a protection against an exposure fire it may be a factor in preventing the spread of fire from one floor to another. It is adaptable to simple automatic closing and requires little or no cost for maintenance. Fire may be seen through it, and, being breakable, it may be used as a shield by firemen while permitting a hose nozzle to be poked through the glass.

Open sprinklers also, for the most part, depend upon the human element in that they must be turned on. The open sprinkler system has the advantage, however, that it is usually so arranged that all sprinklers may be turned on by a single operation at some point remote from the exposed area. Open

sprinklers have been successful in many instances by not only preventing the communication of fire from one building to another, but by preventing the opening of inside sprinklers from radiated heat and the resultant loss to contents by water.

Tin-clad and iron shutters are equally dependent upon the human element. If shutters are normally closed, except when the building is occupied (at which time there is a reasonable chance that they can be closed promptly), they may be on a par with other types of protection with regard to the human element. When the building is not occupied and shutters are left open it is often practically impossible to close all the shutters in time to prevent entrance of fire.

Automatic inside sprinklers, while often successful in preventing exposure fires from entering a building, do so only at a cost of considerable water damage to contents and cannot save the windows. For this reason, therefore, they are preferable as a second line of defense, leaving the primary protection to open sprinklers, wired glass, shutters or a combination of these.

Assuming that the several types of protection are properly used, there still remain certain physical deficiencies inherent in each type. The open sprinkler requires large water supplies which are often not available when needed; the wired glass window transmits radiated heat and melts under the influence of unusually high temperatures; the iron shutter prevents the direct transmission of flame and radiated heat, but has itself no insulating value. The wooden tin-clad shutter, if properly installed, maintained and closed, has perhaps the least inherent deficiencies of any of the several types mentioned, but is so often not properly used that the records show its performance to be inferior to that of open sprinklers and wired glass windows.

A study of the fires included in this record brings out the fact that for protection against severe exposure a combination of two or more retardants is necessary, confirming the conclusions of the N.F.P.A. Committee on Protection of Openings in Walls and Partitions. Combinations of open sprinklers and wired glass windows, wired glass windows and shutters, shutters and open sprinklers are each undoubtedly superior to any single type of protection alone.

It is unfortunate that this record does not include data on some of the more recent developments in the field of exposure protection. Among these developments is the automatic control and operation of water curtains. No fire experience involving automatic water curtains has been recorded, but an analysis of the failures of open sprinklers indicates that of thirty such failures fourteen are directly traceable to a delay or failure to open the valve of the manually operated system.

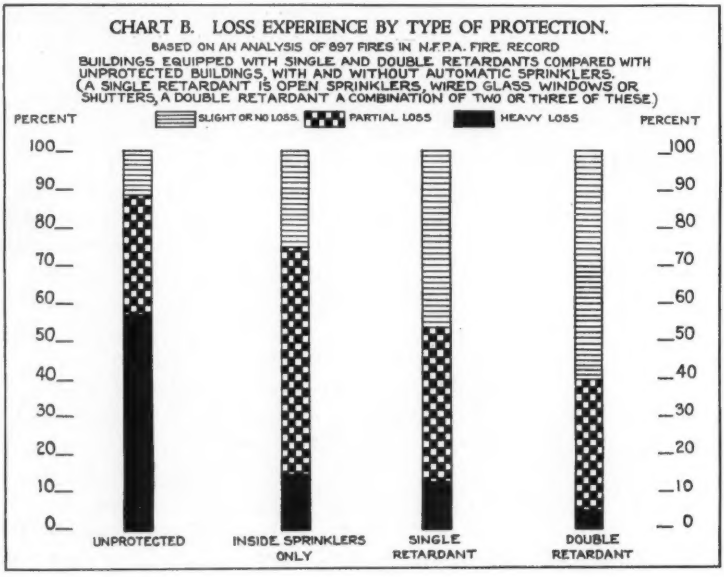
Similarly there is little information available as to the efficiency of automatic rolling steel shutters, there being but two instances of their successful

operation and one failure among the fires recorded. These are of but little value in determining the efficiency of the device as a protection against exposure.

Loss Experience by Types of Protection.

Loss	Unprotected		Inside Sprinklers Only		Single Retardant		More than One Retardant		Total Fires
	No.	Per Cent	No.	Per Cent	No.	Per Cent	No.	Per Cent	
Slight or no loss..	30	11.1	70	25.2	142	46.1	24	60.0	266
Partial loss.....	85	31.1	167	60.0	126	41.0	14	35.0	392
Heavy loss.....	156	57.8	41	14.8	40	12.9	2	5.0	239
Total.....	271	100.0	278	100.0	308	100.0	40	100.0	897

The table of Loss Experience by Type of Protection shows the relative losses with single and double retardants as compared with buildings, both sprinklered and unsprinklered, having no exposure protection. The same data are presented in a chart (B) for more convenient reference. Automatic inside sprinklers are of obvious value as additional protection for buildings equipped with open sprinklers, wired glass windows or shutters, and in a large number of the fires in this record automatic sprinklers were an important factor in preventing the spread of fire which had penetrated the window protection. It is not practicable, however, to show this in a table or chart.



In the following discussions of the several types of protection it will be noted that the dividing line between success and failure of the window protection is not sharply drawn. This is necessarily a matter of judgment in many cases, and the classification of any given fire as a success or failure for the protection involved depends upon a number of factors, such as the severity of the exposure fire. The criterion taken in this classification is whether protection is or is not the deciding factor in preventing an exposure fire from entering the exposed building. For example, if an open sprinkler system results in the saving of an exposed building, this is classed as a success for the open sprinkler system even if one or two of the heads become clogged and it is necessary to back up the open sprinkler system by hose streams at one or two windows. On the other hand, if a building protected by wired glass windows, for example, is exposed and combustible material inside the windows is ignited by radiated heat and the fire is extinguished by an inside sprinkler system, the case may be classified as a failure for the window protection if it appears that inside sprinklers would have saved the building even if there had been no wired glass and the glass was not of material assistance.

Wm. E. Patterson.

Not all exposure losses are due to the fire itself. Two days after a fire destroyed the upper floors of a seven-story mercantile building in Pittsburgh a portion of the wall fell, severely damaging the adjoining four-story structure.

Open Sprinklers.

There have been 156 fires recorded where the exposed building was equipped with an open sprinkler system. In 93 cases the system functioned satisfactorily; in four cases the system was partially successful in keeping fire from the exposed building, secondary protection also being a factor; in 30 cases the system failed to protect the building; and in 29 cases the system was not a factor. In view of the fact that in most of these fires the exposure was severe, this is an excellent showing. Disregarding the 29 cases in which

the system was not a factor, the above figures indicate that in 76% of all fires involving open sprinklers their operation was satisfactory.

The record shows that where the open sprinkler system has fulfilled its designed function, that is, where it has continually *wet* all exposed windows and exposed combustible surfaces, it has been practically universally successful. Failures have occurred only where for some reason the open sprinklers have not wet all exposed areas. If the open sprinkler system is well arranged and maintained, backed up at all times by plenty of water under good pressure, and if someone who knows how to turn it on is at hand, it is of unquestionable value even under the most severe exposure conditions.

An interesting example of the application of exposure protection to residential property was furnished in the Mill Valley, California, conflagration on July 2, 1929. This fire occurred in a thickly wooded district containing many substantial and valuable dwellings. A forest fire swept up the canyon, destroying 130 homes, most of which were of frame construction. Two, however, were saved despite the fact that the fire raged fiercely about them for hours. Both had wooden shingle roofs, but were equipped with roof sprinklers which functioned successfully.

An analysis of the 30 failures indicates that 13 of them were due to the failure of someone to put the manually operated system into operation, one was due to a delay in turning on the system, and four were due to mechanical injury to the system, such as explosions or falling walls. These failures cannot be attributed to the inadequacy of the system.

Reason for Failure	No. Fires
Water not turned on	13
Inadequate water supply	4
Fire penetrated water curtain	4
Explosion wrecked system	3
System not on exposed side	2
Delay in operation of system	1
Conflagration conditions	1
Falling wall wrecked system	1
High wind blew water away from building	1
Total	30

Following are brief summaries of some of the more interesting and typical fires which have occurred during the past few years in which open sprinklers were involved. These fires are typical both of successful operation and of failures.

Typical Fires Where Open Sprinklers Were Successful.

SEPTEMBER 3, 1925, SOMERVILLE, MASS. A frame building used for the barreling of tanner's oil was severely exposed by a fire which destroyed a two-story frame metal-clad building 25 feet distant. The exposing plant contained about 30 carloads of kindling wood and about 150 tons of coal. This made a very hot fire.

International.

Lumber yards present a severe type of exposure, developing a hot, quick fire, spread both by radiated heat and flying embers. Open sprinklers were an important factor in protecting an adjoining manufacturing plant at this fire, which occurred on July 4, 1930, at Boston, Mass.

The protection of the exposed building against an exposure fire consisted of a line of open sprinklers at the cornice. These sprinklers were promptly turned on and were successful in keeping the fire from the building. The owner also knocked open three sprinkler heads on a shipping platform which extended close to the burning exposure. The damage to the exposed plant was limited to a few broken windows and scorched paint on a tank car. (S-40242.)

JANUARY 4, 1926, LAWRENCE, MASS. Fire occurred in a three-story frame building in the mercantile district occupied on two floors for the storage of hardware supplies and on the third as a dwelling. The fire made rapid headway and within a few minutes had extended across a 14-foot alley toward a four-story brick department store building. This latter building was equipped with tin-clad shutters at all windows on the first floor, open sprinklers on the upper floors, and inside automatic sprinklers.

The shutters were closed and the open sprinklers were turned on as soon as possible. With an adequate volume of water available at good pressure the water curtain proved not only an effective barrier to the spread of the fire, but an aid to the firemen, who were able to direct their streams into the burning building under the protection of the open sprinklers.

Except for the cracking of a few lights of glass on the second floor no damage was done to the exposed building. Some water entered the building around the windows on all floors, causing a water loss estimated at $1,100. The automatic sprinklers did not operate. (S-41308.)

JANUARY 29, 1926, WATERBURY, CONN. Less than ten feet away from a large five-story brick manufacturing plant was a row of three-story frame buildings which constituted a severe exposure hazard. The factory windows facing the exposure were provided with wired glass in metal frames. Above the windows on the third and fifth floors outside sprinklers were installed having ½-inch outlets. Ample water for these sprinklers was available, and the watchman had been instructed how to operate the system.

During a terrific gale, with the wind blowing toward the factory building, a fire occurred at 3:00 A.M. in the frame row. There was some delay on the part of the fire department in getting to the fire, due to the fact that a large fire was in progress elsewhere in the city, and the fire consequently gained considerable headway. Several hundred gallons of alcohol in the burning structure contributed to the intensity of the flames.

As soon as the magnitude of the fire became apparent, the watchman opened the valve controlling the open sprinklers and at the same time the plant fire pump was started, providing plenty of water at good pressure. So effective was this protection that no fire damage was done to the factory building except for the cracking of a few panes of glass.

As the fire progressed, water was driven into the building around the windows by the combined action of the outside sprinklers, the strong wind and hose streams used by the fire department. Brooms and sawdust were used by the night cleaning crew of the plant to confine the water to the area adjacent to the wall. Considerable heat radiated through the water curtain and the windows, and windows were opened on the side away from the fire to prevent the operation of automatic sprinklers within the building. The loss was less than $1,000 and entirely due to water. (S-41738.)

JUNE 3, 1926, LOWELL, MASS. A five-story brick tenant manufacturing building was severely exposed by a fire which seriously damaged an adjoining four-story brick department store to the north and west. The protection against this exposure on the west, a distance of about 80 feet, consisted of a blank brick wall. On the north, a distance of about 25 feet, there were open sprinklers and a single automatic fire door on the second floor and tin-clad shutters on the three upper floors, all of which functioned satisfactorily.

The open sprinklers were operated for eight or nine hours and not only assisted in keeping the fire from the building, but also acted as a screen for the firemen. One automatic sprinkler under a skylight on the top floor also operated for a short time. The water from this sprinkler, together with that which entered around the fire door on the second floor, caused considerable water damage. (H-23460.)

July 27, 1926, SARANAC LAKE, N. Y. Fire starting about 1 A.M. completely destroyed a three-story frame building used as a town hall. This

building was about 12 feet from a three-story frame building occupied by a hardware store and apartment, toward which a moderate wind was blowing. The wall of this latter structure facing the town hall was brick-veneered except for 12 feet in the center which was frame, not veneered. Part of the brick-veneered wall was blank, while the remainder had windows protected by metal shutters. Open sprinklers were provided at the eave line.

Soon after the fire started in the exposure the owner of the hardware store, who lived in an apartment on the third floor, turned on the water for the open sprinklers, which operated satisfactorily, and, with the shutters, kept the fire from entering the building, except at one window where the shutter was left open. A small amount of fire entered through this window, causing the opening of five automatic sprinklers inside. The cornice and the elevator pent house were also damaged by fire, which was controlled by the use of hose streams. Damage inside was mainly from water. (S-44582.)

APRIL 14, 1927, PROVIDENCE, R. I. Fire occurred in a very old and poorly constructed mercantile building, damaging it beyond repair. Adjoining this structure was a nine-story fire-resistive building having wired glass windows and open sprinklers on the exposed side. When the fire started these open sprinklers were turned on by the watchman and prevented any damage to the exposed building, except one light of glass that was cracked by the heat. (H-24492.)

JULY 24, 1927, MEMPHIS, TENN. A food products plant consisted of two ordinary brick joisted buildings and a one-story frame iron-clad warehouse. The warehouse was located six feet from the three-story brick building, and the openings in the brick wall facing the warehouse were protected by double fire doors, shutters or wired glass windows and open sprinklers.

The fire, which started in the warehouse, had gained such headway that the entire structure was involved when the alarm was turned in, and the flames were being driven by the wind against the wall of the adjoining brick building. The firemen turned on the open sprinklers on their arrival, which, with the other protective devices, kept the fire from the main building. No sprinklers inside the buildings operated, and the only loss suffered was a slight wall damage, a few melted panes of wired glass and water damage to contents due to water seeping through the broken window panes. (S-45414.)

JANUARY 2, 1928, SHERBROOKE, P. Q. The building involved in this fire was a four-story brick factory occupied as a textile plant. About 50 feet away was a frame livery stable in which a fire was discovered at 5:30 A.M. The fire department, located across the street, was quickly on the scene and soon had four hose streams in operation on the stable. When the flames threatened the factory building the night watchman turned on the open sprinklers, which effectively protected the exposed windows and prevented fire from entering.

The water curtain was operated about fifteen minutes until the firemen had the stable fire under control. Water seeped in through the windows, causing a small water damage to stock. (S-46906.)

FEBRUARY 2, 1928, FALL RIVER, MASS. Open sprinklers proved to be effective barriers in retarding the spread of a fire of conflagration proportions which swept through six blocks in the principal mercantile section of the city. Originating in a group of unsprinklered vacant mill buildings of large area, the fire had gained considerable headway before discovery, with the result that the main building was well involved when the fire department arrived.

Radiated heat from the burning mill buildings severely exposed structures directly across the street, which at this point was approximately 50 feet wide. In spite of the fact that the wind was in such a direction as to carry the heat away from these buildings, the exposure was severe, and two three-story brick buildings were soon ignited and completely destroyed. Separated from these two buildings by a 10-foot alley was the old Fall River Herald Building, also exposed by the burning mill. This structure had a complete automatic sprinkler system and open sprinklers over the windows. These open sprinklers were turned on by a local sprinkler contractor who had charge of

The windows in the upper part of this fire wall on the Fall River, Mass., Globe Building were protected by open sprinklers. These functioned so efficiently during the conflagration, that the thin glass was not even cracked.

During the conflagration of Feb. 2, 1928, the window openings in the wall of the Fall River, Mass., Telephone Exchange building were exposed by the burning of a large wooden building only a few feet away. Open sprinklers, wired glass windows in metal frames and tin-clad shutters effectively kept the fire from the telephone building, although smoke seeping through caused a temporary interruption to service.

this property and prevented the fire from gaining a foothold on this building, although windows were broken and six sprinkler heads opened inside. This building was vacant at the time. The absence of combustible contents near the windows may have been a factor in checking the spread of the fire.

From the mill buildings the fire swept through a group of mercantile structures, including a theatre and a hotel, and finally crossed North Main Street, involving the Wilbur Hotel, a four-story brick building. At this time the course of the fire changed to a northerly direction with another shift in the angle of the wind. The fire was checked in its northerly spread along North Main Street by the wall on the south side of the Globe Building. This was a brick wall, blank except for a few windows opening into a court which were protected by open sprinklers. These open sprinklers operated so successfully that the ordinary thin glass in these windows was not even cracked.

While checked by the wall on the south side of the Globe Building, there was nothing to stop its northerly spread to the Beth-El Synagogue, which fronted on Bank Street, but extended back into the center of the block. This synagogue, which was principally of frame construction, was totally destroyed. At this point the building of the New England Telephone and Telegraph Company, adjoining the synagogue, was severely exposed. Wooden tin-clad shutters and wired glass windows, reinforced by outside sprinklers, prevented the fire from entering this building, but the smoke was so thick that it was necessary for the operators to abandon their post for six hours. (H-25753.)

FEBRUARY 23, 1928, CAMDEN, N. J. A two-story brick tannery formed an "L" on two sides of a one to two-story brick and metal clad building occupied by a textile concern. The distance between the buildings on the exposed sides was about 10 feet. Open sprinklers and wired glass windows were provided in the tannery building against exposure.

When fire occurred in the textile building, which was partially consumed, the open sprinklers were put into operation and were a considerable factor in preventing serious damage to the tannery. All the wired glass windows facing the fire were cracked and the metal sash buckled slightly. Eight automatic sprinklers in the tannery also opened when heat from the exposure fire became too intense. The loss was moderate and chiefly from water. Had it not been for the open sprinklers and wired glass, severe damage would have resulted. (S-47160.)

MARCH 15, 1928, DIXON, ILL. Fourteen feet from a three-story concrete wire mill was a two-story and attic building, having stone walls with floors and roof of wood joist construction, used for the storage of electrical equipment. The exposed wall of the wire mill had wired glass windows in metal frames and open sprinklers.

A fire occurred in the early morning in the stone building, and when the superintendent of the wire mill was notified the fire had broken through the roof. The mill fire brigade was already at work with two hose streams from a standpipe in the penthouse, and the open sprinklers were immediately turned on. A private pump taking water from a near-by canal was able to supply sufficient water for both the standpipe lines and the open sprinklers.

The open sprinklers operated for a half hour and, with the wired glass, prevented the fire from entering the building. Some water, however, leaked in around the window frames and damaged wire cloth to the extent of from $300 to $500. (S-47524.)

APRIL 28, 1930, HOLYOKE, MASS. When discovered, this fire had attained considerable headway in a large unsprinklered lumber shed and soon involved a three-story frame building adjoining. This created a severe hazard to the main buildings of the woodworking plant located from 10 to 20 feet away and consisting of two three-story brick and one three-story frame structures.

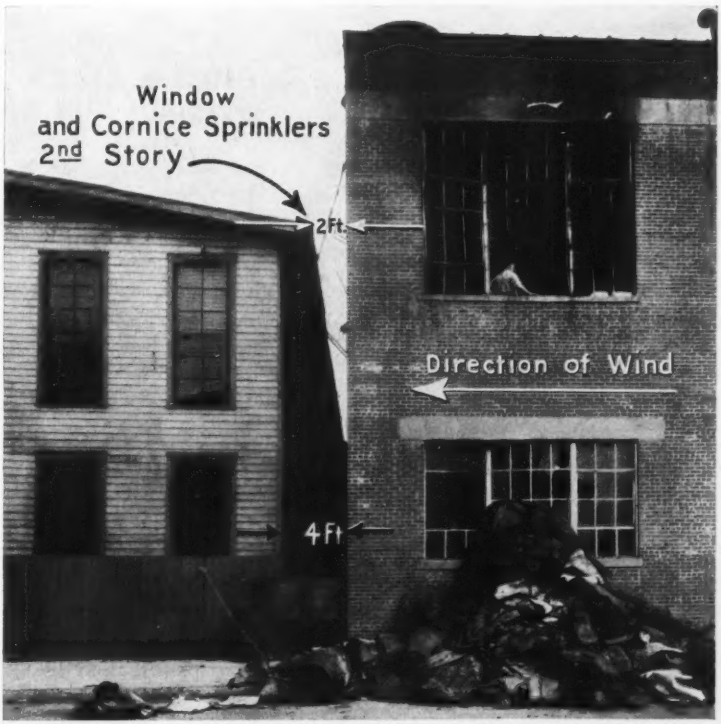
The exposed buildings were equipped with automatic sprinklers throughout. They were provided with plain glass windows on the exposed side and had open sprinklers over each window on the second and third floors. These open sprinklers were put into service early in the fire and were maintained in continuous operation. They were undoubtedly a vital factor in preventing the spread of the fire to these buildings.

In addition to the open sprinklers more than thirty automatic sprinklers in this group of buildings opened. Numerous hose streams were also used,

and while the damage by fire to these buildings was comparatively slight, the water caused considerable loss.

While open sprinklers in this instance were an important factor in preventing a more serious loss, it is evident that where such a heavy exposure existed as from the large frame lumber shed, wired glass windows were needed in addition to the open sprinklers to assure complete protection. The presence of a watchman on the property was undoubtedly an important factor in connection with the use of the open sprinkler protection, and unless, as in this case, prompt and intelligent action will be taken, manually operated sprinklers will not provide the desired protection. (S-52308.)

SEPTEMBER 9, 1930, PATERSON, N. J. The burning of an unsprinklered two-story brick rug factory severely exposed an adjacent textile finishing



Factory Mutual Record.

When fire occurred on Sept. 9, 1930, in this Paterson, N. J., jute rug factory (right), the employees of the adjoining plant (left) promptly turned on the window and cornice sprinklers with which the latter building was equipped. Supplied by a 1000-gallon fire pump, these sprinklers kept the fire out of the wooden building in spite of the proximity of the intense heat and flames.

plant, but outside window and cornice open sprinklers protected the exposed plant from serious damage.

The building occupied by the finishing plant had walls partly of wood and partly of brick, and was located but four feet from the burning building. Outside open sprinklers having ½-inch and ⅝-inch orifices, supplied by ample sized piping, were provided at window openings and along the cornice. When the fire occurred employees turned on the open sprinklers, started the fire pump, and manned three hose streams on the roof, fed from their own yard hydrants.

The open sprinklers gave excellent protection. In spite of the intense heat and flames so near the wooden wall, no fire entered the exposed building, no windows were broken by the heat, nor did the heat penetrate the water curtain sufficiently to fuse the automatic sprinklers inside.

In the brick portion of the exposed building falling débris broke several windows, through which heat entered and fused ten automatic sprinklers, causing moderate water damage. The flames extended above this brick section, burning several small holes in the roof and destroying one skylight before the fire was extinguished by hose streams. (H-56949.)

Typical Fires Where the Operation of Open Sprinklers Was Unsatisfactory.

JUNE 28, 1925, ROCHESTER, N. Y. Lightning struck and set fire to a 1½-story concrete block garage located about two feet from a brick garage. The fire was not discovered until about 20 minutes after the lightning struck, and by the time the fire department arrived the entire attic was ablaze and the adjoining building was threatened.

Open sprinklers were provided at all windows facing the exposure, but in the excitement no one thought to open the controlling valve. The garage employees claimed not to have known about the open sprinklers. One automatic sprinkler in a dormer window in the attic operated and kept the fire from entering at that point. Hose streams protected the other windows. The fire burned the window frames and broke the glass in all the windows exposed. (S-40257.)

SEPTEMBER 3, 1925, SOMERVILLE, MASS. Fire originated in a frame metal-clad building occupied by a coal and wood company and seriously exposed a four-story brick paper-bag factory located approximately five feet away. The protection of the bag factory consisted of open sprinklers over each window on the second and fourth floors supplied by city water and fire department connection, and automatic sprinklers throughout.

The open sprinklers were not operated and fire entered the building on the three upper floors, opening nine automatic sprinklers on the top floor,

nine on the third floor, and fourteen on the second floor. The opening of these sprinklers and water from hose streams caused a large water loss which probably would have been prevented had the open sprinklers been turned on. (S-40241.)

JUNE 4, 1927, MONTGOMERY, ALA. A four-story brick hotel equipped with manually operated outside sprinklers and automatic sprinklers inside was damaged to the extent of $84,000 in a conflagration which swept through two city blocks in the wholesale district. The hotel was in the direct path of the fire, which swept across a 120-foot street.

The first ignition occurred on the mansard roof, from which the fire spread downward into the building. Fire also entered through openings on the north and east walls. These openings were protected by manually operated sprinklers, but for some reason they were not used. These open sprinklers were supplied through a connection to city water mains and by a connection for fire department pumpers. Had this water curtain been used with hose connection from a pumper the loss to this property undoubtedly would have been minimized.

As it was, the fire department used two hose streams, but due to a strong wind they were ineffective and did not reach the roof. The fire worked its way down into the third floor, where it was controlled by the automatic sprinklers inside and hose streams. Practically all sprinklers operated except a few on lower floors and basement. (H-24624.)

JULY 7, 1927, LAWRENCE, MASS. The sprinklered section of this grain elevator and mill was protected from the unsprinklered portions by open sprinklers, which, had they been operated, would have minimized the damage in the sprinklered sections of the plant. The firemen thought that the open sprinklers were automatic in operation and they did not know the location of the post indicator valve, which was in the yard. So the open sprinklers were not used. The fire was held in check by the inside automatic sprinklers and extinguished by 25 hose streams. The loss was about $30,000. (S-45246.)

SEPTEMBER 7, 1927, SHERBROOKE, P. Q. A tar kettle used in roof resurfacing work was located in a ten-foot space between a frame garage and a four-story brick building occupied by a textile manufacturing plant. A slight fire occurred in the kettle and a workman in the garage directed a small hose stream into it from a near-by window. This agitated the contents and caused flames to mount high into the air. The asphalt shingles on the outside wall of the garage ignited and the fire spread rapidly over the wall.

The exposed factory windows facing the garage were protected by open sprinklers, but the engineer who was familiar with the sprinkler system was away, and in the excitement no one thought to open the valve. Fortunately the city fire station was just across the street and the fire was quickly con-

trolled with one hose stream. The heat cracked about 175 small panes of glass, and a door and several window frames were charred. (H-46100.)

OCTOBER 10, 1927, ROCHESTER, N. Y. Fire started in a five-story brick factory adjoining a five-story brick warehouse. It had evidently gained considerable headway before it was discovered, and the entire building above the second floor was involved. The fire jumped across a seven-foot court and entered the warehouse through windows on the three upper floors, burning the window sash and frames and igniting chairs piled near the windows. Thirty-one sprinklers operated on these three floors and prevented the further spread of the fire in this building, but the contents were wet down from the fifth floor to the basement.

There were open sprinklers protecting all the windows facing the exposure where the fire occurred, but for some unknown reason no attempt was made to place them in operation. Had these sprinklers been in operation at the start of the fire the loss would have been slight. The fire department was not aware that the sprinklers were in operation inside the warehouse until the fire was out in the exposure and water was seen running from the first floor into the street. The water loss was heavy. (S-46196.)

FEBRUARY 2, 1928, FALL RIVER, MASS. A mill storehouse was severely exposed in the conflagration. (See page 206 for performance of other open sprinklers in this fire.) The exposed wall was equipped with open sprinklers at the cornices. These were not turned on, as the master mechanic of the mill was not allowed to enter the fire lines for this purpose. The overhanging wooden cornice was burned away in places, and two sets of large unprotected doors in the end and side of the building were ignited. This allowed the fire to reach the roof inside, where it was held in check by automatic sprinklers. (H-25753.)

AUGUST 10, 1930, BUFFALO, N. Y. A fire in a dilapidated and vacant two-story frame building located 10 feet from a three-story brick manufacturing plant seriously exposed the latter building on all three floors. This building was provided with open sprinklers, but the decrepit and elderly watchman (who did not speak English) failed to open the valve, and the fire department, although aware of the presence of an open sprinkler system, for some reason failed to make use of it.

The fire gained considerable headway and, before it could be controlled, damaged the wall of the brick building somewhat, burned the window frames and broke the glass in about twenty-five windows and caused the operation of about 20 sprinklers in the building. The water from these sprinklers caused considerable loss to the contents of the factory, consisting of glued-up wooden chucks. (S-55334.)

DECEMBER 28, 1930, HARRISBURG, PA. A one-story frame machine shop was totally destroyed by a fire which seriously exposed the adjoining three-

story brick tenant building. The exposed building had windows of plain glass in steel sash in the wall facing the fire. Open sprinklers were provided for the protection of the windows on the third floor.

The watchman of the building had not been instructed as to the presence and use of the open sprinklers, and they were not put into operation during the fire. The plain glass windows held remarkably well, practically all being badly cracked, but the glass for the most part remained in position. The heat against these windows was so great that the window shades were badly scorched. One sprinkler head located near a window opened and may have prevented the entrance of the fire at this point. Windows on the first floor were broken, and heat operated several sprinklers in the building. The damage was chiefly from water. (H-56048.)

Wired Glass.

One hundred and thirty-one fires were recorded where the exposed buildings were equipped with wired glass windows. This protection was satisfactory in 73, or approximately 65%, of the cases where wired glass was a factor. In 12 cases the protection was partially successful in that wired glass kept the fire from entering the building, but minor damage resulted from heat radiated through the glass, causing ignition of combustible materials or the operation of automatic sprinklers near by. Wired glass failed in 26 cases, and in 20 it was not a factor. The record clearly shows that wired glass is an effective protection against exposure of moderate severity. Where the exposure is of unusual severity, it should be supplemented by other forms of protection. Where no such supplementary protection is provided, even though the glass remains in place, sufficient heat from severe exposure fires may radiate through the glass to ignite combustible contents.

An analysis of the failures indicates that in the majority of instances the failure may be in part attributed to the intensity and severity of the exposing fire. It is probable that in most of these cases additional protection in the form of open sprinklers or shutters should have been provided.

Reason for Failure	No. Fires
Wire glass melted	15
Glass fell out of sash	2
Falling wall broke glass	1
Automatic window failed to close tightly	1
Failed—no details	7
Total	26

The performance of wired glass windows in the Fall River conflagration* of 1928 furnished a number of interesting lessons both as to the value of this form of protection and the serious consequences of the neglect to provide adequate protection for windows exposed in the path of a sweeping fire.

*This experience is the subject of a special report, "Wired Glass Windows in the Fall River Conflagration," copies of which are available at the N.F.P.A. Executive Office.

Typical Fires Where Wired Glass Was Successful.

JANUARY 12, 1927, ONEIDA, N. Y. A very hot fire occurred in a frame metal-clad building located about 10 feet from a three-story brick storehouse. The exposed wall of the storehouse was provided with wired glass windows, a large number of which cracked but held. The wall was somewhat damaged by the intense heat, and in one place was cracked from the ground to the roof. The wood cornice was burned. Radiated heat caused several sprinklers to operate which, with a hose stream, assisted in keeping the fire from the building. (S-44622.)

FEBRUARY 6, 1927, CHICAGO, ILL. A four-story brick-joisted unsprinklered building occupied as a woodworker was entirely destroyed by fire, severely exposing a five-story brick sprinklered building located approximately 10 feet away. The latter building had all openings toward the fire protected by wired glass windows, with iron fire doors at each end of a bridge between the two buildings.

The wind was a factor in diverting heat from the fire away from the sprinklered building, but sufficient heat was radiated through the wired glass

A fire which destroyed a three-story mercantile building in Sioux City, Ia., severely exposed an adjoining mercantile building and a large department store located across a narrow alley. Both of the exposed buildings were protected by wired glass windows which remained intact.

windows to cause the automatic sprinklers to operate. The wired glass windows were undoubtedly an important factor in preventing the spread of fire into the building and did not show any serious damage from their exposure to the fire. (H-24229.)

MARCH 11, 1927, PITTSBURGH, PA. A fire started on the second floor of a three-story brick-joisted building occupied for the manufacture of ice cream cones. By the time the fire department arrived the entire floor was involved and the fire was spreading through the building. Frame dwellings, separated by narrow alleyways, adjoined the burning structure on either side. Wired glass windows, with which the factory building was equipped throughout, hampered the firemen in getting hose streams into operation, but at the same time were instrumental in keeping the fire entirely within the building and preventing possible damage to exposures. (H-24813.)

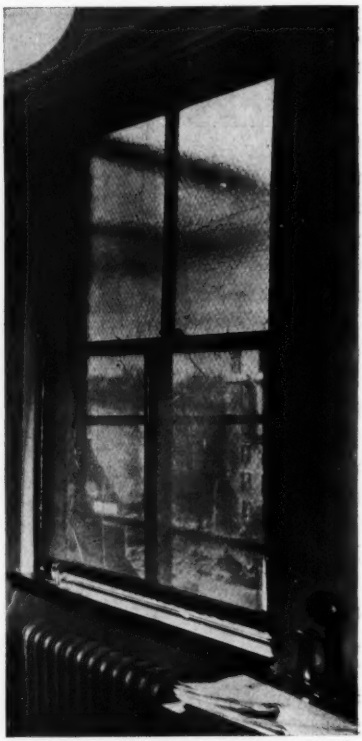
DECEMBER 25, 1927, BRADFORD, PA. A group of one and two-story frame stores burned, almost causing a conflagration. Across a creek, a distance of about 50 to 60 feet, was a garage having wired glass windows in metal frames on the side facing the fire. Radiation from the burning structures caused intense heat inside the garage near the windows, but no ignition took place. Over 1300 panes of glass were badly cracked and had to be replaced, but no fire entered the garage. (H-25506.)

JANUARY 25, 1928, FALL RIVER, MASS. This was a serious and threatening exposure fire which occurred in a two-story brick unsprinklered mercantile building adjoining a similar three-story sprinklered building. The fire involved the second floor of the smaller building, and although the roof did not collapse a large skylight permitted heat and flames to escape with considerable intensity.

On the third floor of the exposed building six windows overlooked the roof of the burned building, being located about three feet above it. These windows were protected by wired glass in fixed metal frames with pivoted metal sash. The occupant of the building reported that the windows most severely exposed were extremely hot, yet they remained intact except for a few small heat cracks and did not radiate sufficient heat to open any of the near-by sprinklers. (S-46728.)

FEBRUARY 2, 1928, FALL RIVER, MASS. One of the most interesting features of the conflagration which swept through the mercantile section of this city was the almost complete burning-out of the six-story fire-resistive Buffington Building. This building was an excellent example of protection provided by wired glass windows in metal frames and at the same time an example of the lack of protection afforded by ordinary plate glass windows in wood frames. It was a clear-cut illustration of the importance of street-front window protection. This fire-resistive structure had wired glass windows on the rear and end, where it was in the direct sweep of the conflagration.

These wired glass windows held, but after the fire had swept around the end of the Buffington Building and ignited buildings across the street, the heat from these burning structures across a street 75 feet wide radiated against the wind, broke the plate glass windows on the front of the Buffington Building and ignited the contents, which were almost completely burned out with the exception of offices on the street floor. (H-25753.)



Typical wired glass windows in the Buffington Building, Fall River, Mass., which withstood the effects of the severe exposure in the conflagration of Feb. 2, 1928.

APRIL 22, 1928, CLEVELAND, OHIO. A fire in a one-story garage adjoining an electric substation generated sufficient heat to crack 160 wired glass panes in the substation, but fire did not enter the building. The garage and contents were destroyed. This fire indicates the effectiveness of wired glass in steel sash as a protection against exposure, as all the panes remained in place and formed a barrier against the fire. (S-47636.)

JUNE 1, 1928, CHICAGO, ILL. A rubbish fire was burning unattended in a small courtyard. Presently the fire spread to the three-story wooden porches on several brick tenement houses which overlooked the court. Fed by the thoroughly dry woodwork, the flames spread to the interior of the tenement houses and other adjacent frame structures.

Across the alley, a distance of about 20 feet, the exposed brick wall of a tenant mercantile and manufacturing building had wired glass windows in steel frame. A light wind carried the heat diagonally toward this wall. About one hundred panes were cracked, but the glass remained in place and kept the fire out. Radiated heat was not great enough to open sprinklers inside. (F.M.R.).

JANUARY 12, 1929, WASHINGTON, D. C. A four-story fire-resistive building was severely exposed by a fire which occurred in a four-story brick-joisted

Factory Mutual Record.

Woodworking plant in Philadelphia, Pa., damaged by fire July 13, 1929. Ruins of large frame lumber shed in foreground. Wired glass in metal frame held in building at the left. Plain glass fell out and wooden frames burned away in building at right. Automatic inside sprinklers operating in both buildings prevented the ignition of combustible contents at the expense of considerable water damage.

building situated across a 20-foot alley. The fire-resistive building was provided with wired glass windows in metal frames. Manually operated rolling steel shutters over part of the windows were open at the time of the fire. These were apparently closed during the progress of the fire, but not before the wired glass was badly cracked. No fire entered the exposed structure. (H-27387.)

JULY 13, 1929, PHILADELPHIA, PA. A fire which completely destroyed a large frame lumber shed severely exposed two other buildings located a short distance away. One of these buildings had wired glass windows in metal frames on the wall facing the exposure. The wired glass cracked but did not fall out. Just around the corner on each side the windows were of plain glass in wooden frames. The frames ignited, the plain glass cracked and about 10% of the glass fell out. Nine sprinklers operated in the building, probably due to heat entering through the broken side windows, although radiated heat through the wired glass may have been a factor. A moderate water loss to the contents of the building resulted.

The other building facing the exposure had plain glass windows in wooden frames. The glass quickly cracked and fell out. The wooden frames ignited and burned away. Thirty-six automatic sprinklers inside opened on both floors and kept the fire from entering, but at a cost of much damage to finished wood handle stock stored in the building. (F.M.R.)

When a group of factory buildings was destroyed by fire in Jersey City, N. J., a large fire-resistive warehouse across the street was severely exposed. The windows of the warehouse were protected by wired glass, which prevented fire from entering. Some of the windows were open, but the fusible links functioned and the windows closed automatically.

MARCH 20, 1930, KNOXVILLE, TENN. A seven-story fire-resistive department store was in the center of a group of two to four-story brick-joisted buildings that were destroyed by a fire which threatened to reach conflagration proportions. The fire-resistive building was equipped with automatic sprinklers, with exposed openings protected by wired glass in metal frames. Although only 10 feet from the exposing buildings, the wired glass windows withstood the intense heat satisfactorily and remained intact, although many were badly cracked. Radiated heat caused several sprinkler heads to operate, causing a water loss to contents. (H-29271.)

DECEMBER 1, 1930, NEWARK, N. J. When a large church was destroyed with a loss estimated at $250,000 a new seventeen-story fire-resistive office building was severely exposed. Although there was a 25-foot clear space between the buildings, the heat was so intense that paint on the interior woodwork of the office building was badly blistered. The wired glass windows of the office building cracked, but they prevented serious damage. (H-28671.)

DECEMBER 10, 1930, BOSTON, MASS. Wired glass windows faced an exposure at only three feet in a six-story brick building occupied by wholesale mercantile firms. When a hot quick fire involving pyroxylin material swept the exposure, these windows held and kept the fire from entering the exposed building. Radiated heat opened two sprinklers, one on the third and one on the fourth floor, causing a moderate water damage. (H-30561.)

Typical Fires Where Wired Glass Failed to Furnish Satisfactory Protection.

MARCH 22, 1922, NEW YORK, N. Y. Fire occurred in a ten-story fire-resistive unsprinklered building, exposing a seventeen-story fire-resistive sprinklered building across a 10-foot light well. The windows of the seventeen-story building were protected by wired glass in sub-standard metal frames. The fire caused the wired glass to crack and fall out in part from the second to seventeenth floor. Some stock in paper boxes stored on the window sill at the tenth floor ignited. One sprinkler operated and extinguished this fire. (S-32244).

JULY 30, 1923, STOCKTON, CAL. A ten-story fire-resistive office building was severely exposed by a fire in an adjoining three-story brick hotel of large area. Window openings above the hotel were protected by wired glass in metal frames. The heat generated by the fire was intense and its full force was directed against the office building. Fire gained entrance on the fifth and seventh floors, mainly through the radiating heat, igniting wooden trim, curtains and other combustible materials near the windows. Melting of the wired glass at a temperature higher than that for which it was intended may have allowed the fire to enter directly in some cases. The fifth and seventh stories were completely gutted. (H-20130.)

JUNE 30, 1925, BUFFALO, N. Y. A storage shed of frame construction located about five feet from a four-story fire-resistive manufacturing building was badly damaged by fire. The exposed wall of the larger building was protected by sub-standard wired glass in steel sash. This protection failed completely, for the glass, held in place only by putty and small wire clips, fell out along the entire first floor. Firemen stated that these panes of glass fell out early in the fire. Fire was prevented from entering the building by hose streams. On the second floor, where the exposure was less severe, the wired glass held and was but slightly damaged. Two of the sash on this floor closed automatically by fusible links. (H-22403.)

APRIL 21, 1927, BOSTON, MASS. Heat from a fire in an adjoining building entered a garage through automatic wired glass windows which failed to close tightly. One sprinkler operated, protecting automobiles stored at that point. (S-44674.)

APRIL 23, 1927, PERTH AMBOY, N. J. Fire destroyed a one-story tile and frame storage building located about 10 feet from the two-story fire-resistive main manufacturing building. The protection on the main building consisted of sub-standard wired glass windows in steel frames. The flames and heat from the exposing structure cracked the wired glass windows and permitted the fire to enter on all floors, causing considerable damage. Fire fighting operations were hampered by lack of water. (H-24979.)

NOVEMBER 24, 1929, WORCESTER, MASS. This fire occurred in a small one-story frame shed adjoining a one-story brick storehouse which was pro-

tected at the exposed side by two wired glass windows in steel sash. The fire was so intense that the steel sash buckled and several lights of wired glass dropped out, permitting the entrance of fire. Apparently the clips ordinarily employed to hold this type of glass in place were not used. Two sprinklers operated and held the fire in check. (S-56998.)

Tin-Clad and Iron Shutters.

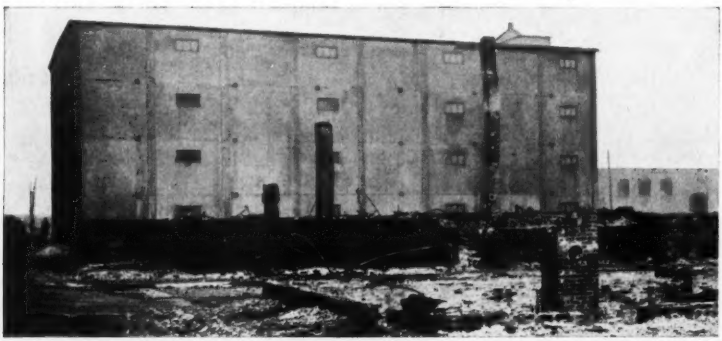
In the previous published record of exposure fires an attempt was made to separate the experience with iron shutters from that of metal-clad shutters. The total number of fires involving iron shutters, however, is so small that no general conclusions can be drawn, so in this record fires involving shutters of all types have been grouped together.

There are in the fire record 102 fires where shutters had been provided as a protection against exposure. The performance of these under fire conditions indicates that in 41 cases the shutters successfully withstood the fire, in three cases they were partially successful, and in 36 cases they failed to protect the building. Twenty-two fires were recorded in which the shutters were not a factor.

The reasons given for the failure of shutters to furnish adequate protection are as follows:

Shutters not closed	17
Fire penetrated thin iron shutters	6
Severe exposing fire prevented closing	1
Automatic device failed to work	1
No data as to reason for failure	11
Total	36

It seems obvious from the foregoing table that the human element is an important factor in the satisfactory operation of shutters as a fire protection



This fire-resistive warehouse was subjected to a severe exposure during the Salem, Mass., conflagration. The wired glass windows cracked and melted out, but inside shutters actuated by fusible links performed satisfactorily, with the result that sufficient heat did not enter the building to operate the sprinklers.

Automatic rolling steel shutters on the exposed windows of the Southern California Telephone Exchange building at Hollywood safeguarded the service of thousands of patrons when fire destroyed an adjoining motion picture studio.

device, 17 of the 36 failures being definitely attributable to this factor. It is clearly shown that standard fire shutters, *if closed,* give satisfactory protection against exposure, and but few instances are recorded where sufficient heat penetrated shutters to cause ignition or to operate the automatic sprinklers adjacent to the exposed windows.

The experience with iron shutters is somewhat less favorable than with tin-clad shutters in regard to heat penetration. The iron shutter heats up more readily and in a hot fire reaches a sufficient temperature to cause ignition of any material which might be in contact with it.

Typical Fires Where Shutters Were Successful.

JUNE 23, 1920, BALTIMORE, MD. A seven-story brick sprinklered building was severely exposed by a fire in a five-story brick unsprinklered building 18 feet distant. The brick walls were badly spalled and the tin-clad fire shutters were badly bulged and twisted and nearly charred through. The fire, however, did not enter the building. A few sprinklers near windows opened. (H-16605.)

NOVEMBER 26, 1921, AUGUSTA, GA. A five-story sprinklered building of mill construction directly adjoined several buildings involved in a conflagration. The tin-clad shutters were closed, and although the wood fillers of the shutters were burned out and the intense heat opened the sprinklers nearest the wall, the fire was checked here, the building suffering little damage. (H-18021.)

APRIL 15, 1924, PITTSBURGH, PA. Fire originated in a three-story brick building and soon spread to an adjoining five-story brick building. The fire seriously exposed a six-story brick building across a narrow alley. The windows of the exposure facing the fire were protected by tin-clad shutters and open sprinklers. The shutters were closed and it was not necessary to use the open sprinklers. (S-37557.)

APRIL 14, 1925, BOSTON, MASS. A furniture warehouse adjoining a two-story metal working plant was seriously exposed by a fire in the latter plant. Wooden tin-clad shutters, provided as protection against this exposure, held perfectly, although the paint on the shutters was all burned off. (H-21935.)

JUNE 17, 1925, BOSTON, MASS. In cleaning up a theatre which was temporarily not operating, a large accumulation of scenery and stage sets was temporarily placed in an alleyway adjoining the building. This material was set on fire by boys and a hot fire ensued. Due to the shutters in the exposed wall being closed, no fire reached the inside of the building. Two shutters were badly damaged and had to be replaced. (S-40533.)

MAY 4, 1927, HOBOKEN, N. J. Two four-story brick buildings occupied for manufacturing purposes were separated by a narrow alley. They were connected by a covered steel bridge protected by fire doors. When a severe fire occurred in one of these buildings the fire doors, iron shutters and wired glass windows were factors in preventing its spread to adjacent buildings. The shutters in part were warped and the wired glass broken, but they held satisfactorily. (H-24669.)

DECEMBER 10, 1930, BOSTON, MASS. When a hot flash fire, due to the ignition of pyroxylin material, occurred in a four-story unsprinklered brick-joist building it severely exposed the adjoining structures, among them a five-story sprinklered building of similar construction. The windows and window casings of this building, on the side facing the fire from the second to the fifth floor, were burned, but fire did not enter the building on any floor, as the openings were protected by inside standard shutters. This is one of the few buildings in the city that is equipped with inside shutters, and in this particular instance they proved quite valuable, as they could all be closed, and prevented the penetration of sufficient heat to fuse the sprinklers. Outside shutters on a similarly exposed building on the other side of the burning building failed to give protection because not closed quickly. (H-30561.)

JANUARY 18, 1931, AUGUSTA, GA. Fire originating in an adjoining building threatened to spread to a three-story department store. All metal fire shutters at all window openings on the third floor of the exposed building were closed and successfully resisted the fire at this point. Fire, however, worked into the roof space and into a partition through an opening in a fire wall. Sprinklers and firemen extinguished these small outbreaks with a nominal loss. (S-55223.)

Typical Fires Where the Protection by Shutters Was Unsatisfactory.

JUNE 23, 1920, BALTIMORE, MD. Fire started in a five-story brick unsprinklered building across a narrow light court from a six-story brick sprinklered building. The windows of both buildings were protected by 1¾-inch tin-clad shutters. The shutters on the fourth and fifth floors of the exposed building were closed, but were forced open by smoke and gas explosions in the burning building. Intense heat ignited wooden frames and sash behind other shutters. All shutters were badly damaged and bulged on both sides. Firemen prevented fire from spreading inside. (S-28100.)

JANUARY 4, 1921, SOUTH NORWALK, CONN. Fire occurred in a four-story brick building adjoining a four-story brick sprinklered building. The fire communicated to a two-story frame addition to the exposed building. Windows of the building overlooking the roof of the addition were poorly protected by sub-standard shutters in wooden frames, the shutters being inside the building and opening inward. The flames reached the unprotected windows and burned out the woodwork, causing 39 sprinklers to operate. Some of the shutters were pushed in by hose streams from outside. The sprinklers controlled the fire. (S-29063.)

AUGUST 3, 1926, BROOKLYN, N. Y. A fire started in packing material in the yard spread rapidly to the roof and window casings of a three-story brick factory building adjoining. The flat iron shutters at the window openings were useless, as they were blocked open by piled cases. Automatic sprinklers operated and prevented the spread of the fire into the building. (S-43065.)

SEPTEMBER 3, 1929, BROOKLYN, N. Y. The exposure fire which communicated to this six-story brick sprinklered manufacturing building started in a lumber yard adjoining. The fire, separated from the building by a six-foot areaway, spread rapidly and was very intense. The windows facing the fire were all provided with flat iron frame metal shutters (except

Fire started in a building at the rear of this factory and communicated to the factory through the window openings, the shutters being open. It was the custom of the occupants of the factory to close their shutters only on Saturday nights.

in the first story), but from appearances after the fire 70% were open, and where closed, the shutters had warped so from the heat that they were of little value in resisting the fire. A large number of sprinklers inside the building operated, draining the system, which allowed the fire to make considerable headway. After some delay, use was made of fire department connections to the sprinklers, but not until serious damage had been done. (S-54912.)

DECEMBER 10, 1930, BOSTON, MASS. A hot, quick fire occurred during the noon hour in a manufacturing plant using considerable pyroxylin material, severely exposing a four-story brick building adjoining. The windows in the exposed building were provided with tin-clad shutters, but due to the rapid spread of the fire it was impossible to close all the shutters, although those on the second and fifth floors were closed. The intensity of the heat was such that the window sills of the building were spalled and shutters at twelve windows were ignited. Sprinklers operated on the third, fourth and sixth floors and were undoubtedly a factor in preventing the entrance of fire into the building. Fire department hose streams were also brought into the building to protect it and to attack the exposing fire from the windows. (H-30561.)

In spite of tin-clad shutters at all exposed windows and an automatic sprinkler system, this Philadelphia, Pa., factory was almost totally destroyed by a fire which originated in an adjoining building. The fire, fanned by a strong breeze, worked its way into the exposed building through cracks around the shutters, some of which opened under the intense heat to which they were subjected. Sprinklers opened rapidly on all floors and within twenty minutes drained the tank. No attempt was made to operate the fire pump until it was too late to be of service, and the building was doomed.

Automatic Sprinklers as Exposure Protection.

Automatic sprinklers, installed inside buildings, are not designed as a protection against exposure fires, and are not ordinarily considered as exposure protection. Experience shows, however, that they are an important factor in exposure fires, and are frequently instrumental in saving the exposed building, though often at the cost of heavy water damage. Failures occur where a large number of heads operate at the same time in a number of floors or sections, the water supplies and pipe sizes, while adequate for an interior fire in any floor or section, being inadequate for the exposure condition.

Among the fires in this record, 535 exposed sprinklered buildings. In 278 cases automatic sprinklers furnished the only protection against exposure. In these fires, as indicated in previous tables, there was not more than a slight loss in 25.2%, partial loss in 60%, and heavy loss in 14.8% of the recorded cases.

One hundred and nine fires exposing sprinklered buildings occurring since 1924 have been selected for detailed analysis, with the following results:

Sprinklers of primary importance in retarding fire	37
Sprinklers of secondary importance in retarding fire	25
Sprinklers not a factor—other protection held fire	31
Sprinklers failed to retard fire	16
Total fires	109

Of the 16 instances where automatic sprinklers failed to retard the fire, all were due to the severity of the fire, which created a condition too difficult for the sprinklers to combat. Several of these instances occurred in conflagrations, where not only the exposure was severe but water supplies were crippled.

Typical Fires Where Automatic Sprinklers Were a Factor.

JULY 21, 1926, FULTON, N. Y. A large manufacturing plant consisting of several brick and frame buildings was severely exposed by a fire which swept through a group of wooden buildings across the street. The buildings of the manufacturing plant ignited at various points (mainly at windows and under the eaves) on the exposed side.

Hose streams, brought into play in spite of the intense heat, were effective in protecting the outside wooden walls, but, inside the building, the automatic sprinklers constituted the first line of defense. When the windows burned out, 33 heads opened along a 200-foot line where the heat was greatest and were successful in preventing the entrance of the fire into the building.

The total loss amounted to about $10,000, largely water damage, much of which would have been prevented had the building been equipped with outside sprinklers in addition to inside automatic sprinklers. (S-42822.)

JULY 8, 1927, PHILADELPHIA, PA. Heat and flames from a burning two-

story frame box factory were carried by the wind against the 200 feet of exposed wall of a five-story fire-resistive manufacturing building. This exposed wall was provided with windows having factory ribbed glass in steel sash. The distance from the exposing building was but 40 feet, and the very intense heat made close approach on the part of fire fighters difficult. All but six panes of glass in the exposed wall were either broken or cracked

Heat entered the building when the windows gave way. Sprinklers in the four upper floors opened first near the windows and then beyond for several bays, until about 150 were operating. These sprinklers, supplemented by employees using hand extinguishers, extinguished a few incipient fires started by sparks and embers. They were shut off after operating for a half hour. Water from the sprinklers and, to a lesser degree, from hose streams spread over the four upper floors and caused a large water damage to stock and machinery. The loss was estimated at more than $25,000. (S-45746.)

The Fall River Herald-News Building and adjoining structures were severely exposed by the conflagration which started across the street. The unprotected buildings at the left were completely destroyed. The newspaper building at the right was equipped with automatic sprinklers. Radiated heat broke the plate glass windows and burned off the cornice, but thirty-two sprinkler heads opening near the windows furnished an inside water curtain which kept out the fire. In spite of water damage, the plant was in operation three days after the fire.

FEBRUARY 2, 1928, FALL RIVER, MASS. Directly across the street from the point of origin of the conflagration was the plant of the Fall River Herald-News, consisting of a four-story building with brick and stone walls and combustible interior construction. Large plate glass windows on the street front were soon broken by the radiated heat from the exposure fire across the street. Automatic sprinklers just inside these windows opened and formed an interior water curtain that prevented entrance of fire. A large wooden metal-covered metal cornice on the street front burned off. Sprinklers in the blind attic prevented the entrance of fire at this point. Thirty-two heads opened and were kept in operation for some time. The linotype machines, printing press motors and other equipment were considerably damaged by water, but three days after the fire the plant was again in operation and turning out eighty per cent of its normal production. (S-46995.)

DECEMBER 20, 1928, NEW YORK, N. Y. This fire occurred in a building which could be distinctly classified as a "conflagration breeder." It was a large area six-story brick-joist unsprinklered structure, occupied for tenant manufacturing purposes. Adjoining or separated by narrow areaways were several fire-resistive buildings equipped with automatic sprinklers.

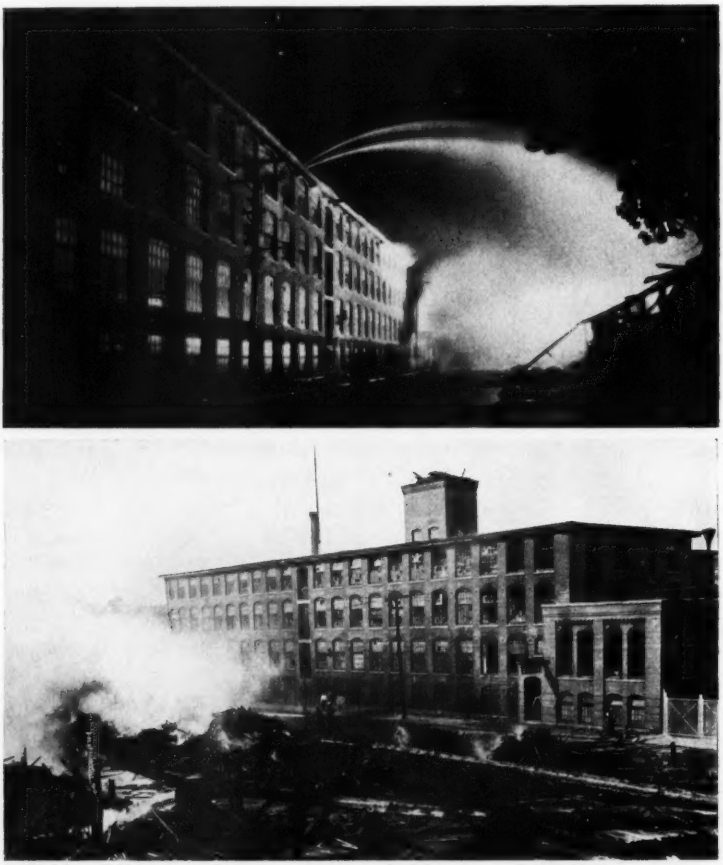
Serious loss occurred in these sprinklered buildings because of lack of standard shutters or wired glass windows, but the automatic sprinklers held the fire in check and narrowly averted a serious conflagration. The chimney-like arrangement of the light courts and the taller buildings surrounding the lower building tended to cause the fire to burn intensely. The heat caused sprinkler heads to operate on eight different floors of one exposed building, almost simultaneously, and indicates that if it had not been for the presence of the sprinklers all eight of these floors would have been ablaze at one time. The operation of a sprinkler head on the sixth floor of another exposed building shows that there was enough heat to ignite the contents of that floor also. (S-49842.)

SEPTEMBER 3, 1929, PAWTUCKET, R. I. A severe fire occurred late at night in a large frame unsprinklered lumber shed (225 ft. by 40 ft.) located across a 60-foot street from a four-story brick mill-type textile manufacturing plant. The wall of the latter building facing the fire was of brick, with an overhanging wooden cornice and windows of plain glass in wooden frames.

In spite of the fact that the direction of the wind was away from this plant, the heat was so intense that the wooden roof of a tower on the main building ignited and burned away. The cornice also ignited. Practically all the windows on the exposed side cracked and fell out. The wooden window frames caught fire, and many of them at one end of the building were practically destroyed.

The heat passed through the windows and opened seven sprinklers in the top story, two in the third, and six in the second story. All these sprinklers

were in the first row inside the windows and prevented the fire from getting a foothold inside, but they did so at a cost of considerable water damage. Water ran from the sprinklers for about two and one-half hours, the valve being closed after the worst of the fire across the street was over and hose streams had extinguished the burning cornice and window frames. (S-50754.)



Factory Mutual Record.

This textile plant in Pawtucket, R. I., was exposed by a fire in a frame storage shed across the street, starting shortly after midnight on Sept. 3, 1929. The fire was fought with hose streams from the roof, but the wooden cornice and ordinary windows did not withstand the heat. Inside automatic sprinklers opened near the windows and saved the building, but there was a loss of $100,000.

Fires in Which There Was Loss of Life.

Since the publication of the July QUARTERLY, the Department of Fire Record of the N.F.P.A. has received from various sources a total of 132 reports of fires in which loss of life has occurred. For the most part the fires recorded have occurred since July 1, 1931. While the number of fires reported to the N.F.P.A. is but a small fraction of the total number that have occurred during this period, the volume of data is sufficient to indicate the predominating causes of loss of life. These reports indicate a toll of 260 lives lost by fire during the period.

The largest single loss of life included in this tabulation occurred in the Little Sisters of the Poor Home for Aged in Pittsburgh on July 24, 1931. This is the largest loss of life ever recorded in an institution of this type in the United States. The story of this fire appears in detail elsewhere in this issue of the QUARTERLY.

The loss of life tables below include eight casualties in connection with forest fires, which, compared with press reports, is but a fraction of the total number that have occurred during the past summer in the forest fires which

Loss of Life Fires, July-September, 1931.

This is a typical rather than a complete record, presented to show the conditions under which loss of life occurs, that they may be known and guarded against. The total loss of life by fire in the United States is estimated at 10,000 annually.

Class of Fire	No. Fires	Lives Lost				
		Men	Women	Children	No Data	Total
Airplane fires	19	35	1	2	0	38
Apartments, lodgings, tenements, etc.	10	8	4	1	4	17
Automobile fires	7	6	4	0	0	10
Church	1	1	0	0	0	1
Dwellings—Rural	22	6	11	22	0	39
Dwellings—Urban	14	4	6	6	0	16
Garages and filling stations	3	6	0	0	0	6
Industrial occupancies	12	20	0	2	0	22
Institutions	3	17	33	0	0	50
Mercantiles	2	2	0	0	0	2
Oil fields	2	10	0	0	0	2
Other buildings	8	6	2	4	0	12
Other than buildings	16	11	0	7	0	18
Powder plant	1	5	0	0	0	5
Railroad property	1	2	0	1	0	3
Response to alarms	5	5	0	0	0	5
Ships and motor boats	6	5	1	0	0	6
Total	132	149	62	45	4	260

This table is made up from reports received by the Department of Fire Record between July 1 and September 30, 1931. A few of the fires included herein occurred prior to July 1, but were not reported until after that date.

have swept the western states. Newspaper reports from Montana dated September 1, 1931, state that a total of fourteen lives have been lost while fighting fires in Montana and Idaho during the past few months, while similar reports from California indicate a total loss of twelve lives in that state.

In two instances the loss of life recorded in these tabulations was due indirectly rather than directly to the fire. In one instance a father died of an infection which resulted from a skin grafting operation, which was performed in the hope of saving the life of his son who had been severely burned. In the other instance the foreman of a department of a large industrial establishment committed suicide after a fire, supposedly resulting from his negligence, which took the lives of four men.

Causes of Loss of Life, July-September, 1931.

Fatalities classified according to the immediate cause of the loss of life rather than according to the cause of the fire.

Cause	Men	Women	Children	No Data	Total
Airplane fires	35	1	2	0	38
Automobile fires	6	4	0	0	10
Children and matches	0	0	10	0	10
Cleaning with gasoline	1	3	1	0	5
Clothing ignited from bonfire and campfire	0	0	2	0	2
Clothing ignited by match	0	1	0	0	1
Clothing ignited from overturned lamp	0	1	0	0	1
Escaping from fire—jumped	0	1	0	0	1
Explosion—asphalt still	1	0	0	0	1
Explosion—refinery	6	0	0	0	6
Explosion—illicit still	0	1	0	0	1
Explosion—kerosene stove	0	3	0	0	3
Explosion—oil field	10	0	0	0	10
Explosion—powder plant	5	0	0	0	5
Explosion—soap tower	2	0	0	0	2
Explosion—cause unknown	2	0	0	0	2
Fighting forest fire	4	0	0	0	4
Filling lamp while lighted	1	0	0	0	1
Fire fighting	5	0	0	0	5
Fireworks and firecrackers	2	0	1	0	3
Gasoline used to start fire	0	1	0	0	1
Ignition of flammable liquids or vapors	19	2	2	0	23
Infection—gave skin for grafting	1	0	0	0	1
Kerosene used to start fire	1	2	2	0	5
Looking for gas leak with match	1	1	0	0	2
Looking for gasoline leak with match	1	0	0	0	1
Overcome by ammonia fumes	1	0	0	0	1
Overcome by smoke—suffocation	7	11	0	0	18
Railroad accidents	2	0	0	0	2
Re-entering burning buildings	3	2	0	0	5
Responding to alarms	5	0	0	0	5
Shock or after effects of fire	3	13	0	0	16
Suicide—after effects of fire	1	0	0	0	1
Trapped by forest fire	4	0	1	0	5
Trapped in burning building	20	15	24	4	62
No data	1	0	0	0	1
Total	149	62	45	4	260

Typical Loss of Life Fires.

Entering Burning Building.

H-32878. BATTLE CREEK, MICH., AUGUST 13, 1931. Watching firemen fight a garage fire was a fatal experience for four men and a painful one for four others. The victims were part of a crowd who rushed into the showroom of the garage in order to better view the flames in the rear of the building. The fire started with an explosion, which occurred when gasoline was accidentally poured into a heated automobile radiator. The crowd viewing the fire from the showroom suddenly found themselves trapped by a backdraft, which caused the collapse of the rear section and sent flames into the front room where the crowd were jammed about the door in an attempt to escape. The four lives were lost before firemen could break a plate glass window to release the victims.

Fire Fighting.

H-32875. NEW YORK, N. Y., AUGUST 27, 1931. A retired banker was burned to death while attempting to extinguish a fire which occurred in his automobile. He was driving alone through a park when fire broke out under the hood of the machine. While he was attempting to smother the blaze with rags an explosion occurred and he was enveloped in flames, which caused him to collapse over the burning machine. Near-by persons extinguished the fire in the victim's clothing, but he was dead before an ambulance arrived.

Gasoline Explosion.

H-32879. BOSTON, MASS., JULY 8, 1931. A gasoline explosion aboard a motor launch resulted in fatal injuries for one man and serious injuries to another. The launch had just left its pier to carry one hundred gallons of motor oil to a vessel in the harbor, when the blast occurred. Presumably fumes in the bilge of the craft were ignited by an electric spark. The man who died was blown from the craft into the water, which was showered with blazing oil.

Gas Explosion.

L-1207. BECKET, MASS., JULY 4, 1931. Gas for cooking and heating water at the guest house of a boys' camp was provided from three large tanks outside the building and adjacent to the kitchen. Apparently gas escaped from one of these tanks and entered the basement, the subsequent ignition and explosion of which resulted in the deaths of two camp attendants and injuries of two others. The explosion occurred with terrific force when the caretaker, who was searching for the gas leak, struck a match in order to locate the electric light switch at the cellar stairs. The clothing of the caretaker and a maid, who was near by, became ignited and both were fatally burned. Two other women employees were injured when blown through the kitchen windows by the blast.

Home Dry Cleaning.

L-1210. NEW YORK, N. Y., JULY 22, 1931. A blaze having fatal results occurred when a bottle of flammable cleaning fluid, which a woman was using in her bedroom, ignited from some undetermined cause, presumably static electricity. The woman apparently threw the bottle containing the blazing liquid toward the door, and then, terrified to find her escape cut off by flames, she jumped from the window of her third floor bedroom and received fatal injuries.

L-1209. WHITE PLAINS, N. Y., JULY 22, 1931. A woman's death was the result of an attempt at dry cleaning with gasoline in the basement of her home. The victim was wearing a pair of kid gloves to protect her hands from the gasoline, reached for an electric light fixture as dusk approached. At that instant the gasoline fumes were ignited either by static electricity from the gloves or by a spark in the electric fixture.

L-1213. HAVERHILL, MASS., AUGUST 3, 1931. A man was fatally burned when a can of flammable cleaning fluid, which he was using in the kitchen of his home, exploded. Fumes from the cleaning fluid were ignited by the pilot light under a hot water heater. An attempt to save his life by jumping into the bathtub was not successful.

L-1214. NEW YORK, N. Y., AUGUST 3, 1931. An explosion of flammable cleaning fluid, which ignited her clothing, caused the death of a fifteen-year-old girl. The reason for the ignition of the flammable fluid is not known, as the girl was working alone in a vacant apartment beneath the one in which she was residing. A policeman, who heard the explosion, beat out the fire in the child's clothing, but not before she had been fatally burned.

Improper Electrical Equipment.

L-1211. WEBSTER, MASS., JULY 24, 1931. Improper electrical fuses were responsible for a blaze which took the life of a young woman and destroyed the cottage in which she was staying. Thirty-ampere fuses were found in the ruins of the dwelling where fifteen-ampere fuses should have been used.

Trapped in Burning Building.

H-32873. NEW YORK, N. Y., SEPTEMBER 19, 1931. An aged man and two women were trapped and burned to death on the top floor of a four-story rooming house. The fire started in a room on the first floor. Firemen responded promptly, only to find that access to the building was effectively blocked by parked automobiles. While the firemen were thus delayed, the fire spread from the room of origin to the stair shaft, cutting off the escape of the occupants of the upper floors.